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Volume 15, Number 4, April 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Reports

Microwave Hazard Measurements Near Various Aircraft Radars

Richard A. Tell[1] and *John C. Nelson*[2]

In order to determine the potential for exposure of individuals when in the vicinity of aircraft radar units when aircraft are on the ground, the Electromagnetic Radiation Analysis Branch monitored four radar units that were typical of radars used by commercial aircraft. Two of the units were surveyed at a radar simulation laboratory and the other units were surveyed while in their operating positions in aircraft.

The survey determined that the radar beams from navigational and weather radar units in commercial aircraft rotate in either a sector-scanned or 360 degree rotation at approximately 15 r/min. The radar beams emanated from the aircraft above 6 feet from the ground. It was determined that power density exposures of 10 mW/cm^2 can occur from 8 to 18 feet from the antenna of an aircraft radar unit.

No radiation levels in excess of 0.2 mW/cm^2 existed in the aircraft cockpits.

This study constitutes part of a continuing effort by the Electromagnetic Radiation Analysis Branch to identify and investigate potential problem areas associated with nonionizing radiation sources in the environment. This effort was aimed at one specific class of microwave emitting equipment—aircraft radar. EPA has an interest in the possible hazards and health implications of all types of nonionizing electromagnetic sources. In this study, the principal concern developed from a desire to know the potential for exposure of individuals when in the close vicinity of aircraft radar units such as when boarding commercial air carriers. The emphasis in this study was not placed on environmental exposure at ground level resulting while aircraft are airborne but rather consists of an examination of possible thermalizing radiation levels near the radars while the aircraft are on the ground.

Data and other pertinent information relating to actual measurements were obtained during a 4-day period (4–7 September 1973) at the Federal Aviation Administration (FAA) Aeronautical Center, Oklahoma City, Okla. During this time, access was provided to a number of the FAA aircraft which are used in training exercises and routine electronic surveillance of air routes in the United States. The radar units in these planes represent a good cross section of the various aircraft radar units used in daily air passenger service in this country and represent normal complements of navigational equipment including weather and navigational radars. Additionally, access was provided to a radar simulation laboratory at which tests could be made on various radars in a test-range environment (rooftop mounted radome with adequate area to make field measurements).

Information relating to typical aircraft radar installations and radar specifications was obtained from the Electromagnetic Compatibility Analysis Center, a Department of Defense installation in Annapolis, Md. which maintains extensive computer files on radiofrequency and microwave equipment.

Objectives

The principal purposes of this study were:

1. to determine the types of radars which are used on board various commercial and private aircraft,
2. to ascertain the pertinent radar specifications which would provide an insight to the potential for hazardous exposure from these units, and
3. to make measurements of radiation levels in the vicinity of several representative radars

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and compare these levels with currently accepted guidelines for safe microwave exposure.

Though the process of theoretically predicting power densities from microwave antennas is an interesting problem, this report does not contain any detailed comparisons of measured data with various analytical approaches because of the complexity of these comparisons. For more information on calculational approaches, particularly of use in the near field, the reader is directed to the appropriate references cited in the text of this report.

Typical aircraft radars

In general, large airplanes used in commercial service (e.g., DC-10, DC-9, B-727, B-707) include at least one radar and sometimes more as a part of their minimal electronic equipment. The primary radar unit normally is used for weather determination, navigation, and general search operations. These radar units are moderately powered, usually in the range of 20 to 100 kW peak power, and, as a rule, have a radar antenna which consists of a parabolic dish mounted in the very front of the aircraft. Many other radiofrequency and microwave sources are found in these aircraft, e.g., altimeters, which commonly use frequency modulated emission, pulsed sources for interrogating ground-based navigational aids such as tacan[3] units, and communications equipment. The airborne radars, however, represent the most powerful of all such equipment found aboard these vehicles and thus present the greatest potential for harmful exposure to nonaircraft personnel if care is not exercised during the operation of the equipment. A summary of radar transmitter characteristics for units found in typical airplanes in use at this time is given in table 1. This table is not intended to be exhaustive but

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[3] Tacan is a condensation of tactical air navigation, a complete ultrahigh frequency polar coordinate navigation system using pulse techniques.

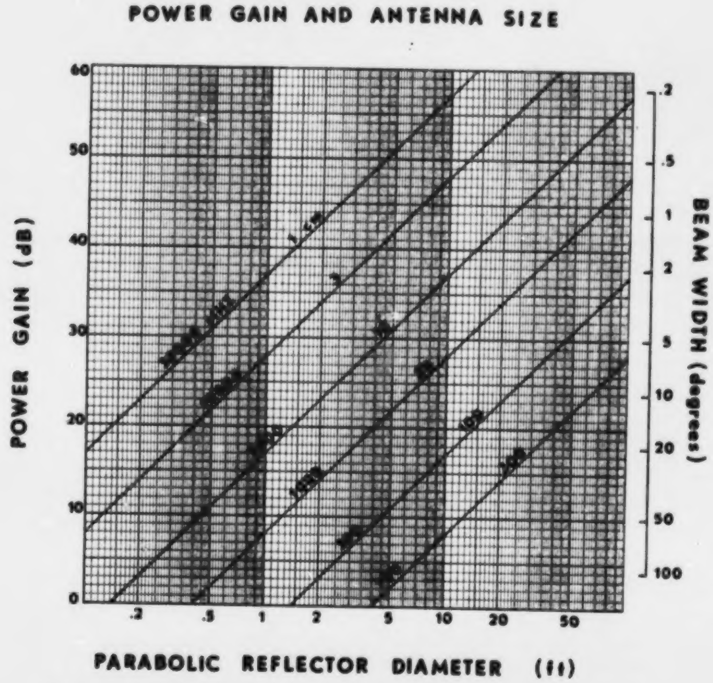

Figure 1. Relationship of dish diameter, gain, and beamwidth for selected frequencies

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Table 1. Typical airborne radar specifications

Manufacturer	Model	Frequency range (MHz)	Peak power (kW)	Antenna gain (dB) [a]	Average power (W) [b]
Bendix	RDR-1A	9345-9405	17	29.5	16
	RDR-1B	9307-9405	40	31.0	25
	RDR-1B2	9345-9405	40	31.0	25
	RDR-1C	5370-5430	100	30.0	80
	RDR-1D	9345-9405	17	29.5	16
	RDR-1E	9345-9405	65	37.1	65
	RDR-1F	9300-9500	65	31.0	80
RCA	AVQ-10	5380-5420	75	28.0	60
	AVQ-20	9335-9415	20	27.5	16
	AVQ-30C	5370-5430	60	30.0	122
	AVQ-30X	9315-9375	60	26.0	69
Collins	WP-101	5370-5430	75	33.0	66

[a] The antenna gains listed here are those for a parabolic antenna dish in a typical radar configuration. Manufacturers normally offer more than one size dish for their transmitter, and thus the gain may vary slightly from one installation to another.

[b] The average power from any particular radar system may have several different values depending on the exact pulse width and pulse repetition frequency (PRF) selected. This column lists the highest of the average powers if more than one is possible.

rather indicative of the specifications of typical airborne radars used aboard large aircraft.

As noted in the table, the antenna gain may vary, depending on the actual antenna size employed. The gain of a parabolic dish is a function of its diameter. Figure 1 illustrates the relationship between dish diameter, gain, and beamwidth for several different frequencies. Gain of a well-designed horn-fed parabolic reflector may be estimated from the relationship (*1*):

$$G = 27\,000/(\theta_H \cdot \theta_E)$$

where:

G = absolute gain above an isotropic radiator,

θ_H = 3 dB beamwidth (in degrees) in the H plane of the antenna,

θ_E = 3 dB beamwidth (in degrees) in the E plane of the antenna.

Radar antenna patterns may be shaped differently. The two most commonly used shapes are a narrow "pencil" beam in which the beam is made as narrow as the dish allows, and a cosecant-squared shape applied to the vertical pattern. A cosecant-squared shape refers to the proportionality in the vertical plane of antenna gain to the cosecant squared of the elevation angle. Such a vertical pattern in practical antennas varies as cosecant squared from about the upper 3 dB point to approximately 40 degrees in elevation. Using a vertical cosecant squared radiation pattern allows constant power density illumination of a target as long as the target maintains a constant altitude.

For purposes of estimating the radiation exposure level from a radar, it is necessary, as a minimum, to know the effective radiated power (ERP) from the antenna. This ERP is a measure of the antenna's focusing power and is equal to the product of antenna input power and antenna gain. At distances on the order of $2D^2/\lambda$ or greater (D is the largest dimension of the antenna, the diagonal for rectangular units, and λ is the free space wavelength of the transmitted wave). The power density (for hazard purposes) may be computed from:

$$W = \frac{PG}{4\pi R^2}$$

where,

W = power density at a distance R from the antenna,

P = power available to antenna (taking into account transmission lone losses), and

G = absolute mainbeam gain of the antenna.

This equation is valid only for points on the axis of the mainbeam of the antenna and at distances which are in the far field. For computations of power density at points within the near field, more complicated techniques are required—in this case, the antenna gain must be corrected for application at near field distances. Though exact formulas are difficult to arrive at, the Army has developed some simple equations for use in the near field of circular parabolic antennas on the basis of empirical data (*2*). Other discussions of near field corrections may be found in the literature (*3,4*).

The power densities computed from any of the equations will be peak or average values depending on the power term entered in the equation. Currently, for hazard purposes, the average power to the antenna is taken as the power which is proportional to the tissue heating effectiveness of the radiation exposure. Peak power densities, especially from pulsed sources such as radars, may be important in various device interferences (*5*). For practical purposes in radar computations, in lieu of actual power measurements, the average power of a transmitter (P_{avg}) is taken as

$$P_{avg} = P_{peak} \cdot PRF \cdot \tau$$

where:

P_{peak} = the peak pulse power (in watts) of the radar transmitter (this is almost always the stated power of radar),

PRF = the pulse repetition frequency (hertz),

τ = the pulse width (seconds).

Figure 2 plots the relation between peak and average power for various PRF's and pulse widths.

Radars and facilities available for test

This section describes the radar units which were surveyed and circumstances under which the measurements were made. It was the intent of the authors to obtain measurement data on several different, but typical, radar types in common use. Under the constraints of the time available, the poor weather conditions, and other measurement projects being conducted during the trip, a total of four radars were surveyed which represent three different models and manufacturers. Prior to making measurements around the radar units mounted in the airplane nose cones, a series of measurements were obtained on similar radars at the radar simulation laboratory. At the simulation facility, actual radars could be operated at will in a relatively controlled environment. Figure 3 depicts the interior of the simulation lab, show-

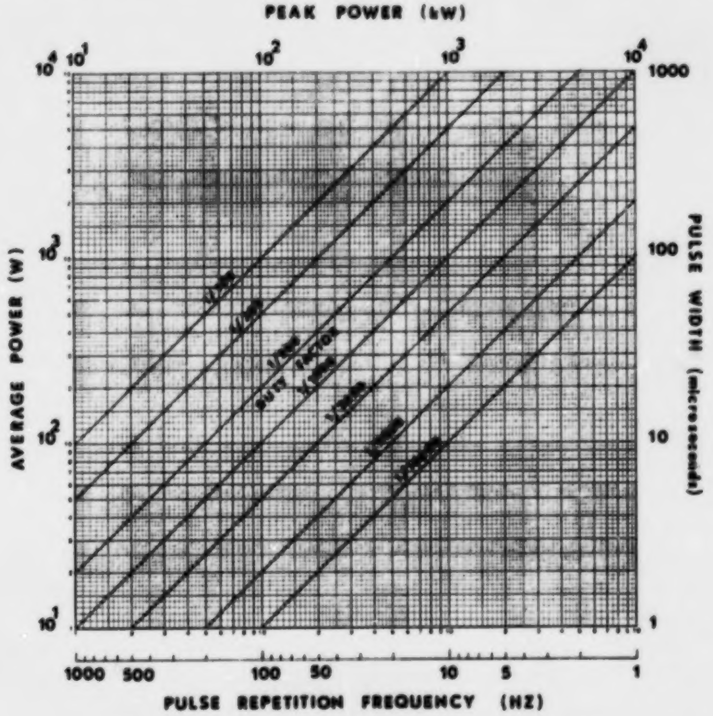

Figure 2. Relationship of peak and average power

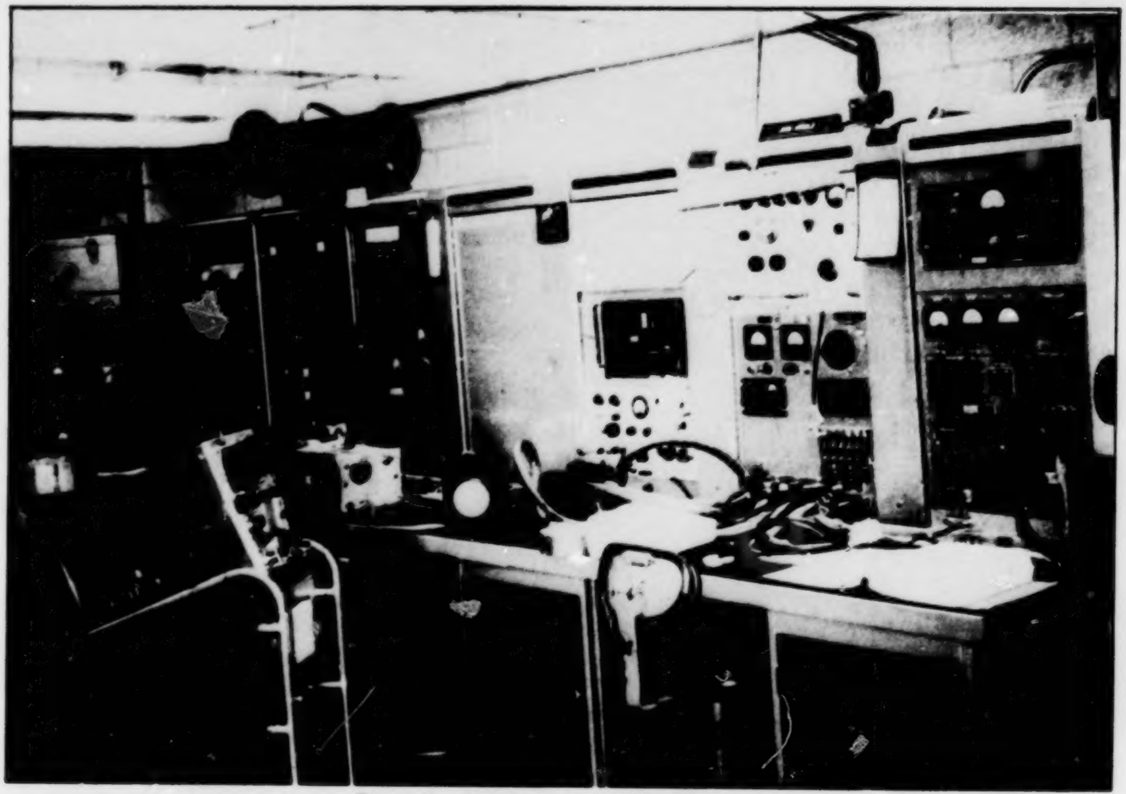

Figure 3. Interior of simulation laboratory

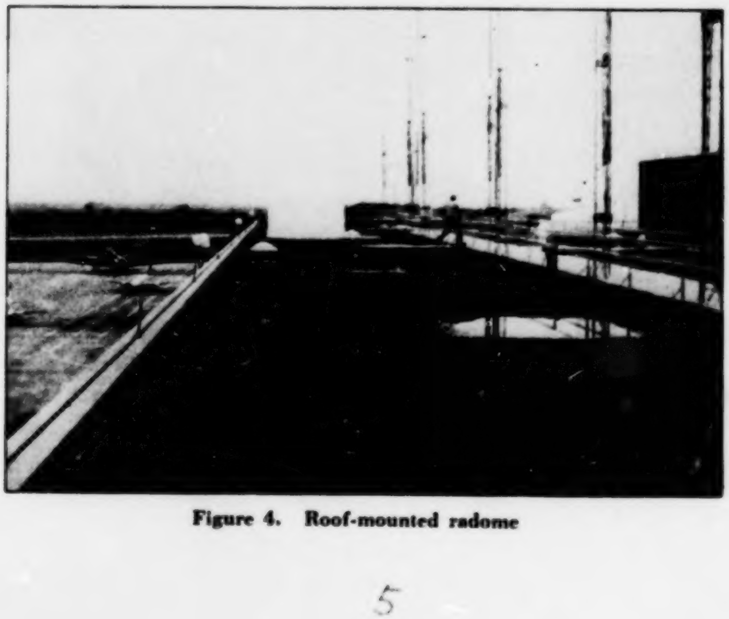

Figure 4. Roof-mounted radome

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ing the various power supplies, test equipment, and radar control panels. The actual transmitter unit and antenna were placed on a platform which could be elevated into a radome structure on the roof above the laboratory (figure 4). Notice the large number of communication antennas in the near vicinity. A closeup view of a typical airborne radar dish antenna is shown in figure 5.

Table 2 lists the radars which were measured and their installation configurations. Detailed specifications for each of these radars may be found in tables 3, 4, and 5. The Bendix RDR-1B is capable of two different pulse widths and these are indicated in the table. Also given in these tables are the calculated values for $2D^2/\lambda$, the far-field distance as computed from reference (*2*) ($D^2/2.83\lambda$), the maximum power density expected in the near-field region based on reference (*3*), and the distance to the point where the field is expected to be 10 mW/cm², assuming a far-field gain for the specific antenna. The gain of an antenna is always a far-field gain unless otherwise stated (i.e., the gain of an antenna is always that gain which is effective at a distance where the power density decreases as inverse square distance).

Table 2. Summary of radars used in measurements

Radar	Manufacturer	Simulation laboratory	Aircraft
AVQ-10	RCA	X	X
RDR-1B	Bendix	X	
WP-103	Collins		X

The two aircraft radar units surveyed were both installed in the nose cones of their respective planes—a Sabre Liner with the Collins WP-103 and a Convair 600 with the RCA AVQ-10. Figures 6 and 7 show these aircraft parked in the flight operations area of the FAA

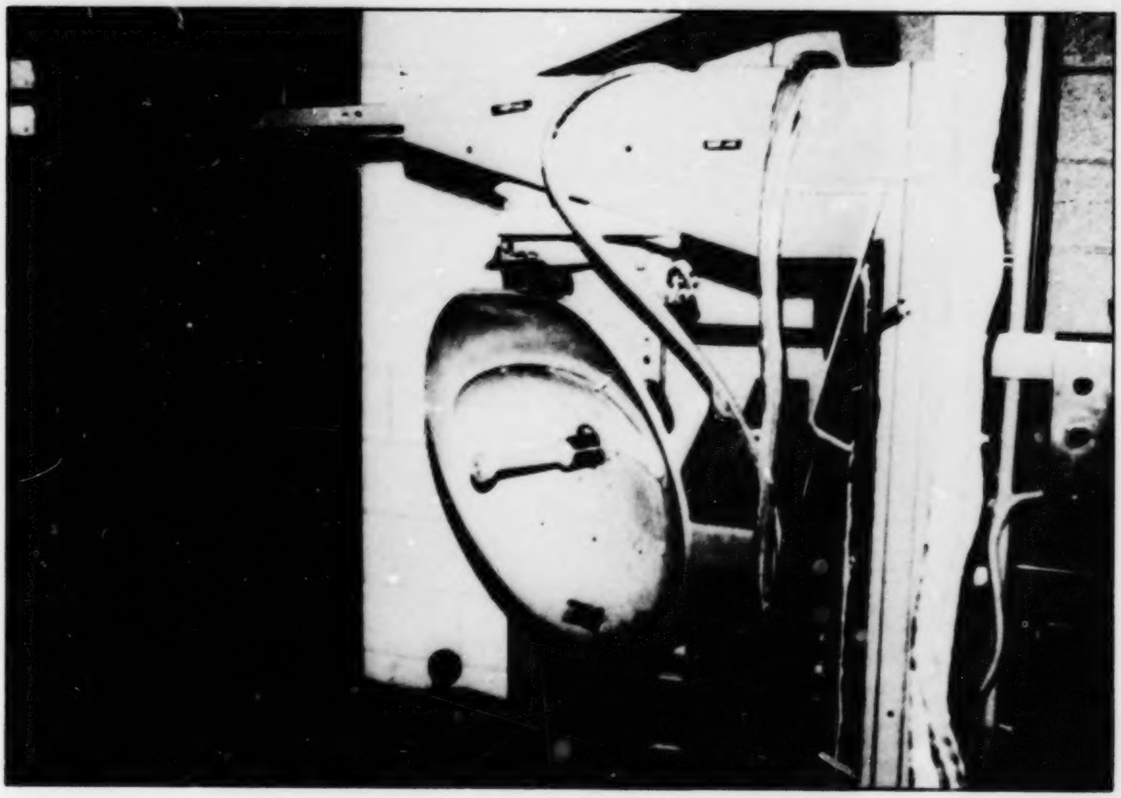

Figure 5. Typical airborne radar dish

Table 3. Specifications for RCA AVQ-10 aircraft radar

Antenna diameter	22 inches	
Transmitting frequency	5400 ±20 MHz	
Wavelength	5.55 cm	
Pulse width	2 μs	
Pulse repetition frequency	400 Hz	
Duty factor	0.0008	
1/duty factor	1250	
Peak power output	75 kW	
Average power output	60 W	
Antenna gain	33 dB	
Maximum average effective radiated power	120 kW	
Antenna scan angle	360°	
Antenna tilt limits	10° up – 15° down	
Antenna rotation speed	15 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	4.5°	4.5°
CSC^2 beam	4.5°	(a)
Polarization:		
Pencil beam	Horizontal	
CSC^2 beam	(a)	
Calculated data:		
$2 D^2/\lambda$	11 m (36 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	2.0 m (6.6 feet)	
Maximum peak power density in near field	120 W/cm²	
Maximum average power density in near field	100 mW/cm²	
Distance to 10 mW/cm² assuming far field gain	10 m (33 feet)	

[a] Information not available.

Table 4. Specifications for Bendix RDR-1B aircraft radar

Antenna diameter	22 inches	
Transmitting frequency	9375 ±30 MHz	
Wavelength	3.20 cm	
Pulse width	1.5 μs search; 2.25 μs beacon	
Pulse repetition frequency	400 Hz	
Duty factor	0.0006; 0.0009	
1/duty factor	1667; 1111	
Peak power output	40 kW	
Average power output	24 W; 36 W	
Antenna gain	30.0 dB	
Maximum average effective radiated power	24 kW; 36 kW	
Antenna scan angle	360°	
Antenna tilt limits	15° up – 15° down	
Antenna rotation speed	15 ± 3 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	3.8°	3.8°
CSC^2 beam	3.8°	(a)
Polarization:		
Pencil beam	Horizontal	
CSC^2 beam	Vertical	
Calculated data:		
$2 D^2/\lambda$	20 m (66 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	3.5 m (11 feet)	
Maximum peak power density in near field	65 W/cm²	
Maximum average power density in near field	39 mW/cm² (at 24 kW ERP); 59 mW/cm² (at 36 kW ERP)	
Distance to 10 mW/cm² assuming far field gain	4.4 m (14 feet) (at 24 kW ERP); 5.4 m (18 feet) (at 36 kW ERP)	

[a] Information not available.

center. Careful examination of figure 7 reveals the nearby control towers and weather radar at Will Rogers Airport.

Survey equipment

All measurements of radiation levels covered by this report were made with a Narda Microwave Corporation Model 8300 broadband isotropic radiation monitor. This monitor consisted of a Model 8321 isotropic probe (rated for a maximum time average power density of 20 mW/cm² for pulsed fields), and a Model 8310 probe readout meter. Salient characteristics of this device are given in table 6. This particular device, Serial Number 02006, was certified as being calibrated 18 June 1973, or approximately 2.5 months prior to the field trip.

Table 5. Specifications for Collins WP-103 aircraft radar

Antenna diameter	12 inches	
Transmitting frequency	9375 ±40 MHz	
Wavelength	3.20 cm	
Pulse width	2.3 μs nominal	
Pulse repetition frequency	400 Hz	
Duty factor	0.0008 – 0.001	
1/Duty factor	1000 (assuming 0.001 DF)	
Peak power output	20 kW	
Average power output	20 W (assuming 0.001 DF)	
Antenna gain	26 dB	
Maximum average effective radiated power	8 kW	
Antenna scan angle	120° sector	
Antenna tilt limits	12° up – 12° down	
Antenna rotation speed	15 r/min	
3 dB beam width:	Horizontal	Vertical
Pencil beam	(a)	(a)
CSC² beam	(a)	(a)
Polarization:		
Pencil beam	Horizontal	
CSC² beam	(a)	
Calculated data:		
$2\ D^2/\lambda$	5.8 m (19 feet)	
Distance to beginning of far field ($D^2/2.83\lambda$)	1.0 m (3.4 feet)	
Maximum peak power density in near field	110 W/cm²	
Maximum average power density in near field	110 mW/cm²	
Distance to 10 mW/cm² assuming far field Gain	2.5 m (8.3 feet)	

[a] Information not available.

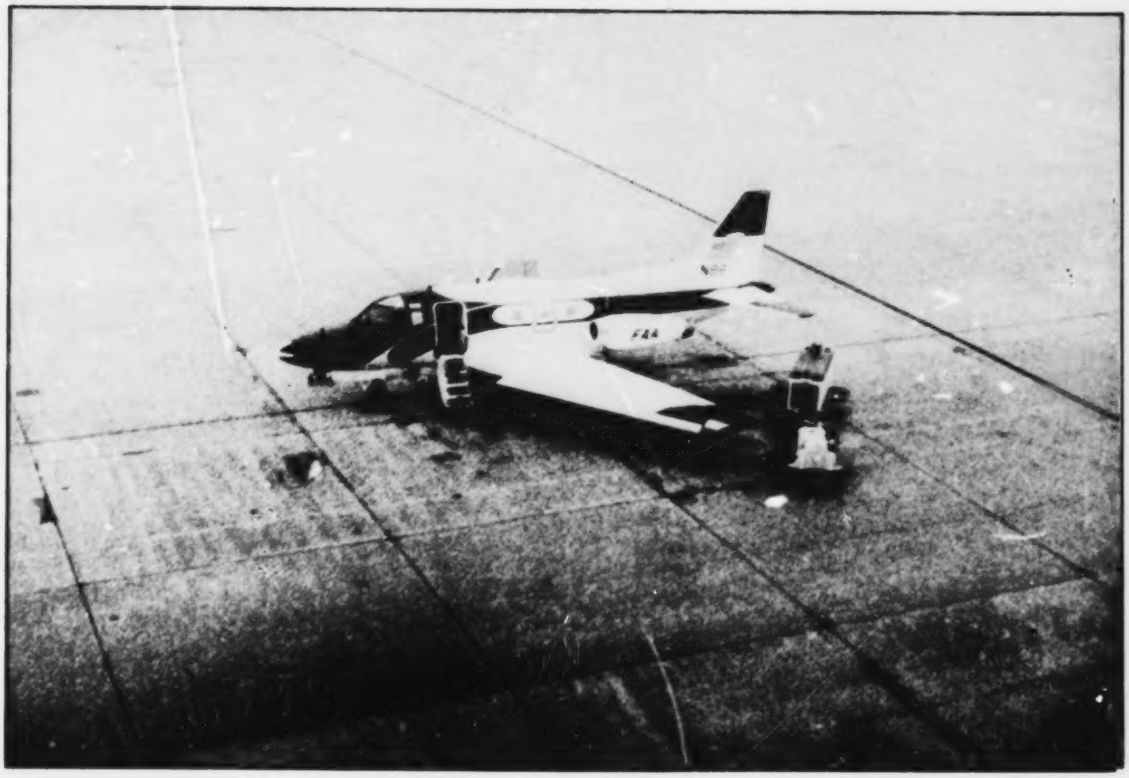

Figure 6. Sabre Liner

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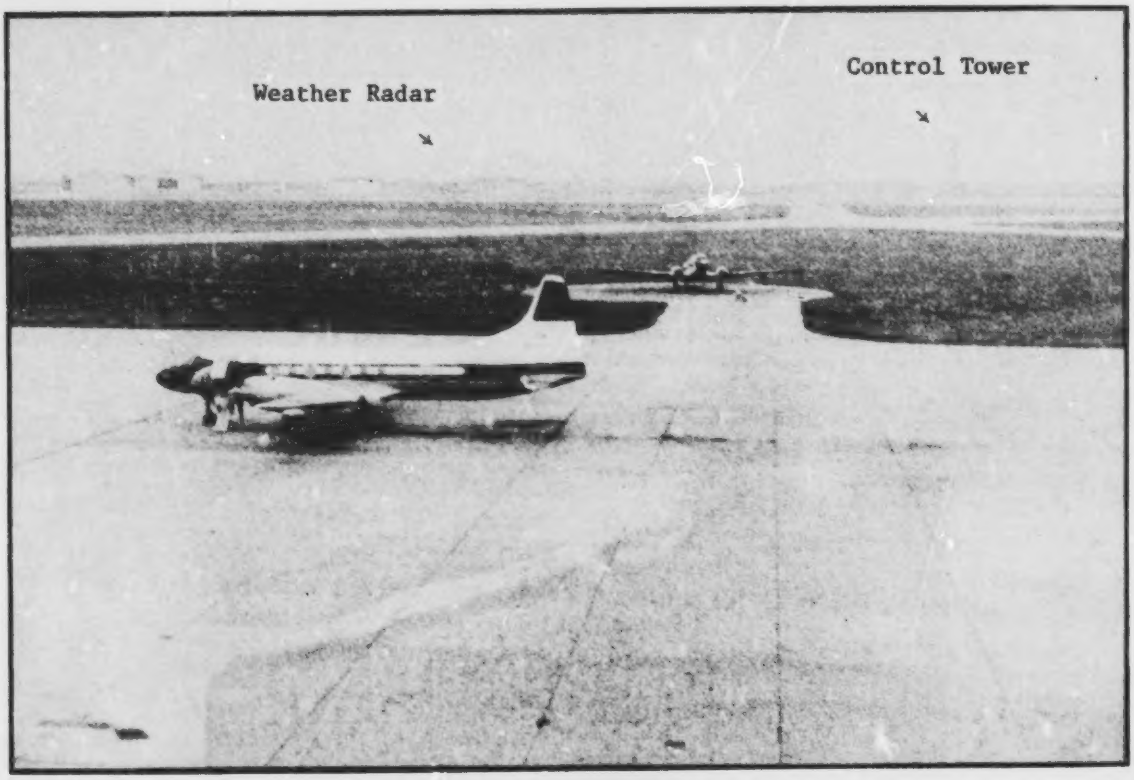

Figure 7. Convair 600

Table 6. Characteristics of a Narda Microwave Corporation Model 8300 broad band isotropic radiation monitor

Frequency range	0.3 to 18 GHz
Power reading ranges	Full scale (two ranges) 2 mW/cm^2 and 20 mW/cm^2
Accuracy of isotropic probe calibration	±0.5 dB
Isotropic probe time constant	20 ms
Frequency sensitivity	
from 1 to 12 GHz	±0.5 dB
from 0.85 to 16 GHz	+0.5, −1 dB
from 0.30 to 18 GHz	+0.5, −3 dB
Isotropic response	±0.5 dB maximum deviation from energy incident in any direction except from and through handle
Response time, including time for meter indicator to to reach 90% of final steady state reading when subjected to a stepped input signal	1.2 s
Accuracy of instrumentation	±3% of full scale
Probe overload rating	
Continuous wave (cw)	100 mW/cm^2
Peak (pulsed emissions)	20 W/cm^2

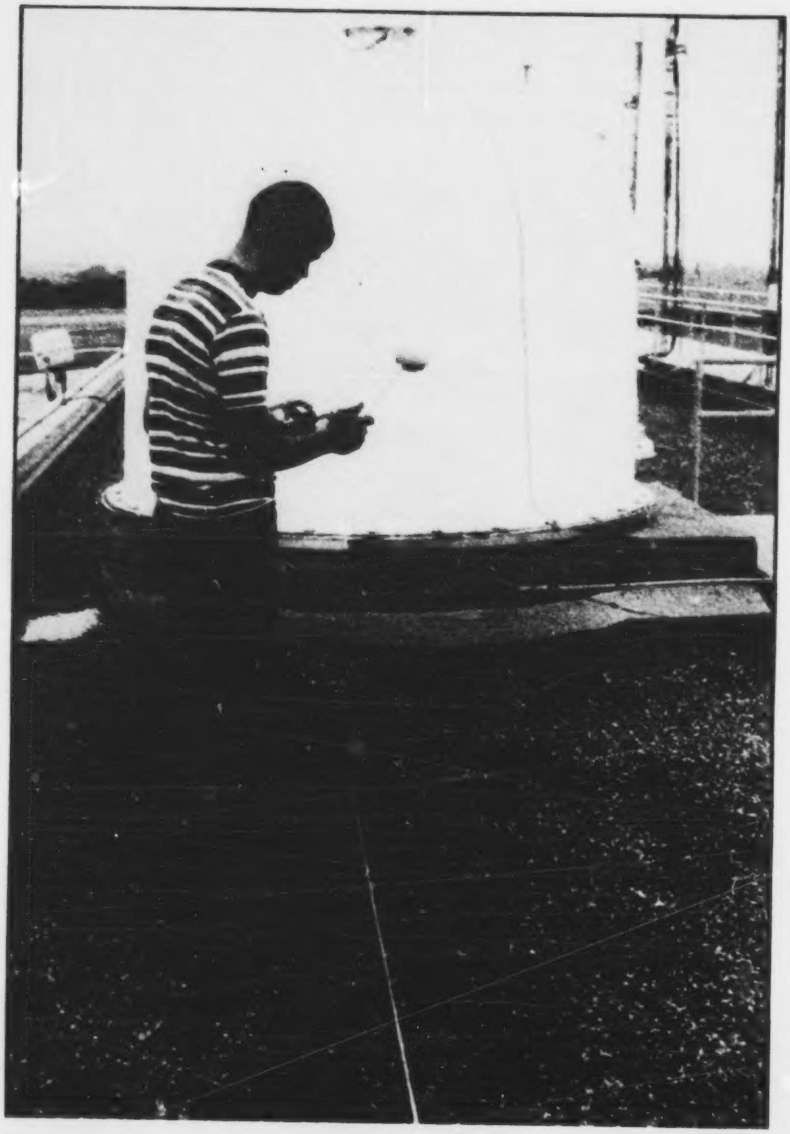

Figure 8. Roof radome survey

Procedures

At the simulation lab, each of the two radars was individually set up so that the radar dish could be elevated to the roof-mounted radome where field measurements were obtained by standing on the flat portion of the roof in the vicinity of the radome. In this manner, a relatively free field situation prevailed, tending to minimize reflection problems. All data were collected with the radar dishes stopped in azimuthal rotation; this was necessary (a) to ensure that all readings were being taken in the

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main radiation lobe of the transmitting dish, and (b) to obtain true readings of maximum levels because the time response of the indicator circuitry was slow. Once the dish was aligned as desired, the RF power was applied, and field measurements were made approaching the radome from a distance of approximately 100 feet. Once a rough feel for the magnitude of the fields was obtained, careful measurements were then made at successively shorter distances to the radome. All such measurements were obtained by holding the isotropic probe in one hand, the metering device in the other hand, and searching for the mainbeam of the dish at each distance. Distances were measured with a 100-foot steel tape laid on the roof. As one individual made the measurements, another recorded the data (field level and distance) at a lateral distance sufficient to not cause noticeable field reflections toward the survey probe. Data was taken in this manner until a distance was reached where the peak power density was equal to the burn-out limit for the survey instrumentation (20 W/cm^2). This peak field value was predetermined in terms of the meter indication of time average power density by taking into account the duty factor of each radar. In practical terms, this imposed a limit in the neighborhood of 15–18 mW/cm^2 average power density for the radars tested.

Figure 8 shows a typical survey reading being taken near the radome. After conducting the mainbeam field measurements for each radar, a survey of the area immediately adjacent to the radome was made, completely encircling the radome except for the mainbeam area in front of the antenna. These measurements were made to determine the possible existence of side lobes and a back lobe for the antenna. Figure 9 shows a measurement being made inside the radome but to the rear of the transmitting dish. In all cases, inadvertent exposure to individuals, other than the authors, was prevented by keeping other personnel off the roof.

A similar approach was used with those radars actually in an airplane. The planes were parked in open areas, clear of obstructions, adjacent to taxiways in accordance with FAA advice (*6*). Measurements were never taken with an airplane parked inside of a hangar. Under such conditions, reflections from other nearby aircraft could cause radar receiver crystal damage. Accordingly, when weather

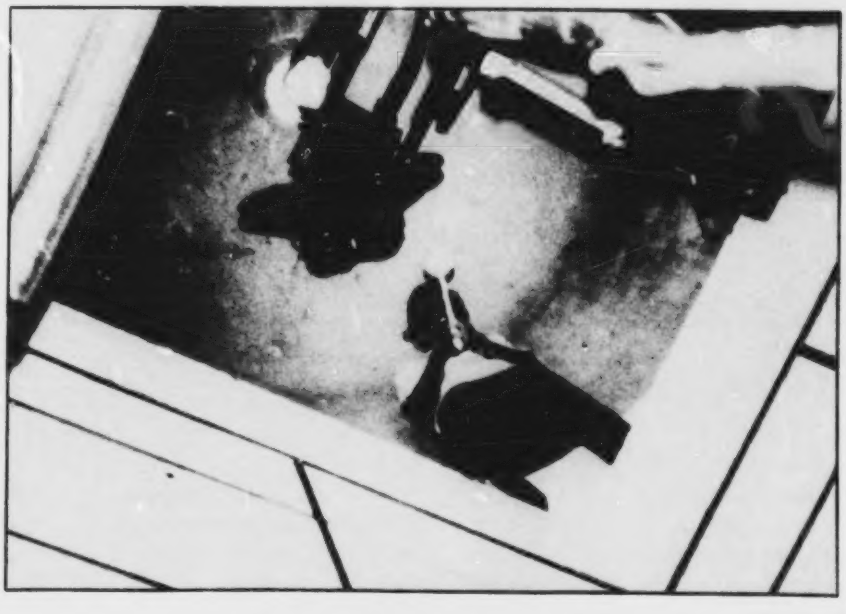

Figure 9. Measurement inside radome

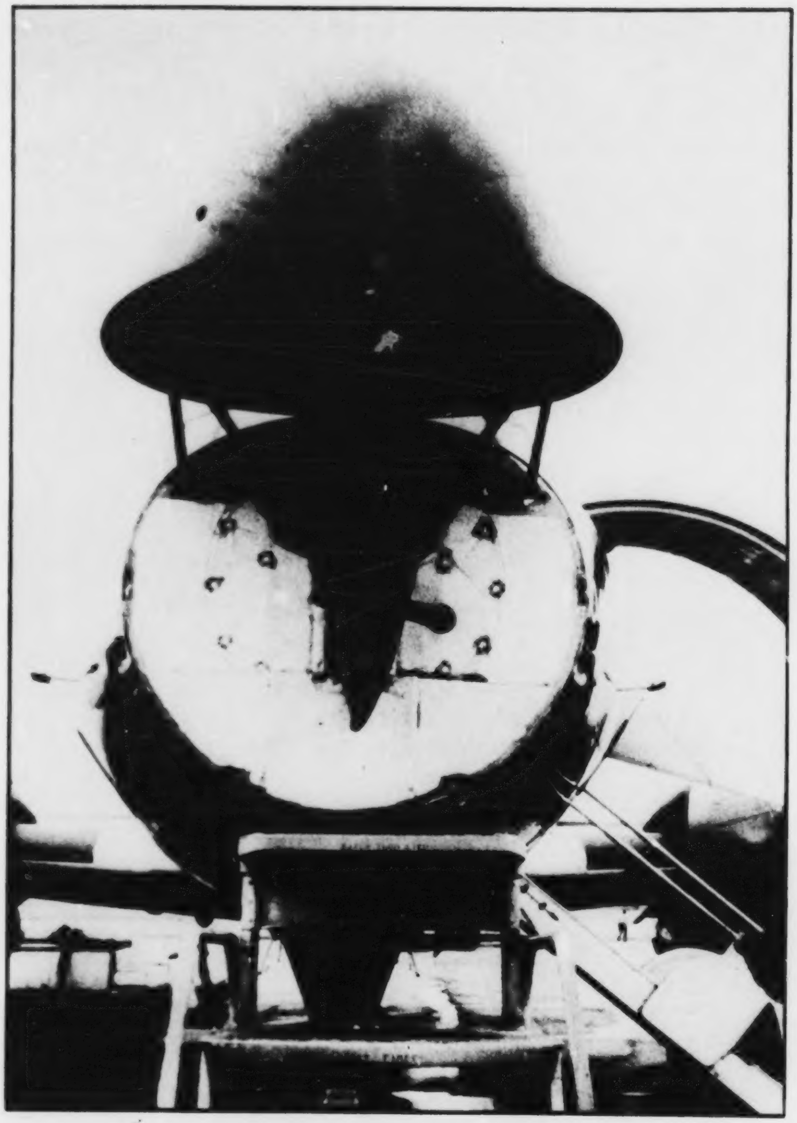

Figure 10. Convair with nose cone lifted

permitted, the selected airplane was moved to the outside location and the antenna fixed in position, pointing straight ahead of the plane. With the Convair 600 (figure 10) the nose cone was lifted on its hinge and measurements made as a function of distance, approaching the nose from a distance. Figure 11 is another picture of the survey of the Convair. Because of the height of the Convair nose above ground, the dish had to be pointed downward at approximately a 13° tilt in order that field measurements could be made from the ground. With

Figure 11. Survey of Convair

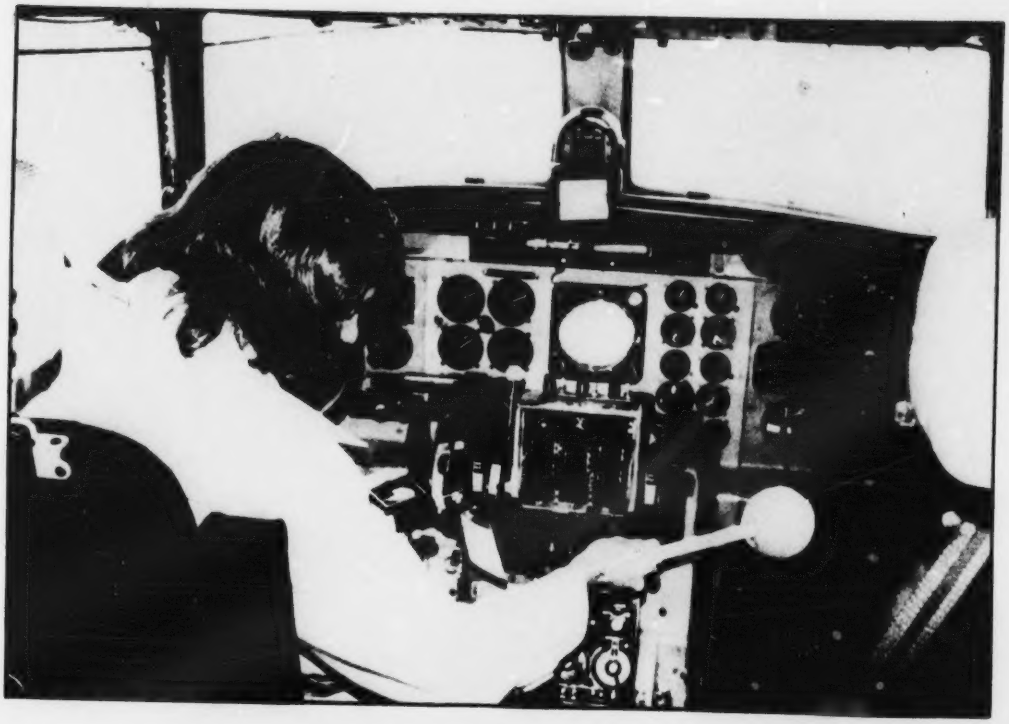

Figure 12. Survey of Convair cockpit

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such an orientation, ground reflections were observed from the concrete apron at certain distances.

Once measurements on the dish axis were completed on the Convair, the antenna was repositioned until it pointed directly toward the cockpit, so that a survey of the cockpit could be made for possible radiation exposure (figure 12). The antenna was then positioned at various angles to enhance possible reflection from wings and other aircraft structures while additional cockpit measurements were made. Notice that the front of the fuselage is a flat metal plate which effectively shields the cockpit from the dish. This plate is covered with an absorptive, anechoic material to prevent receiver failure during the time that the antenna is rotating to the rear, since full 360 degree rotation is used by the AVQ-10.

Finally, a measurement was made of the attenuation properties of the nose cone itself, since our measurements were unattenuated ones. This was accomplished by lowering the nose cone, determining the radiation intensity at a known distance, and comparing with previous unattenuated values at the same distance.

Measurements on the WP-103 in the Sabre Liner were simplified in that the plane is smaller and consequently lower to the ground. This factor allowed the antenna to be kept nearly perfectly horizontal, and thus fewer ground reflection problems were observed. Also, due to the inconvenience of the operation, the nose cone itself was not removed. Instead, a portion of the fuselage shell near the nose cone was removed, so that adjustments could be made for stopping the normal antenna rotation. Figure 13 shows surveying around the Sabre Liner.

Results

The field intensity data resulting from our measurements are plotted in figures 14, 15, and 16. Survey data for the simulation lab measurements on a Bendix RDR-1B and the RCA AVQ-10 are shown in figure 14. Actual data points are graphed and a smooth curve was visually fitted through these points. Also shown on each graph is the distance at which the far field begins, as calculated by reference (2) and indicated under calculated data in tables 3, 4, and 5.

At various distances, more than one power density value was obtained. Such occurrences could be due to (a) practical difficulties encountered in relocating the same exact measurement position with respect to the main beam, and (b) apparent power fluctuations in the RF output from the radar transmitter. This was

Figure 13. Survey around Sabre Liner

14

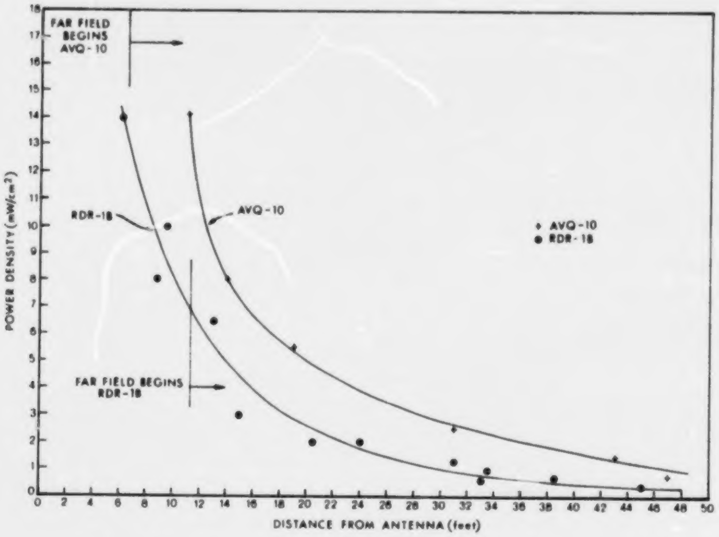

Figure 14. Measurements at simulation lab with radome

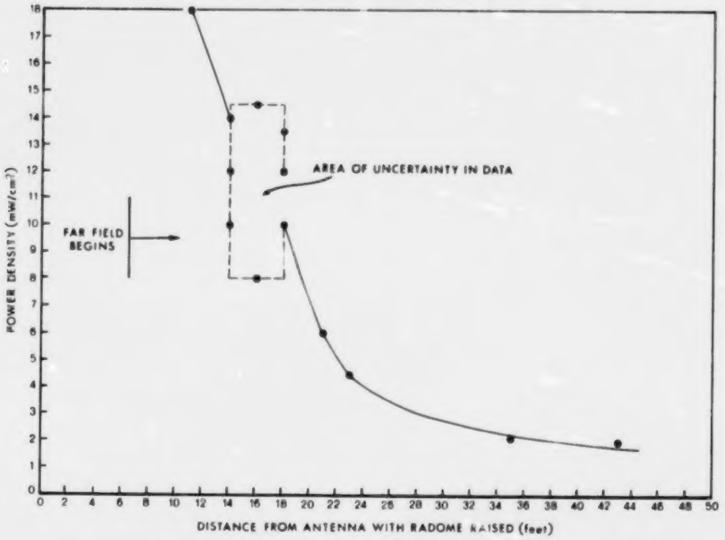

Figure 15. Measurements of RCA AVQ–10 in Convair 600

most evident in measurements on the RDR-1B and the Convair installation of the AVQ-10. In particular, stationary monitoring at a given distance would, from time to time, produce a variation in the power density reading, indicating some transmitter instability. However, notice that the area of data scatter in the RDR-1B measurements falls within the near field range and consequently is possibly an indication of the very erratic nature of this particular region of the exposure field, causing extreme difficulty in repositioning the probe to the same exact point, on a repetitive basis. Table 7 summarizes the data, indicating the distance at which the exposure power density was found to be 10 mW/cm² and 1 mW/cm²

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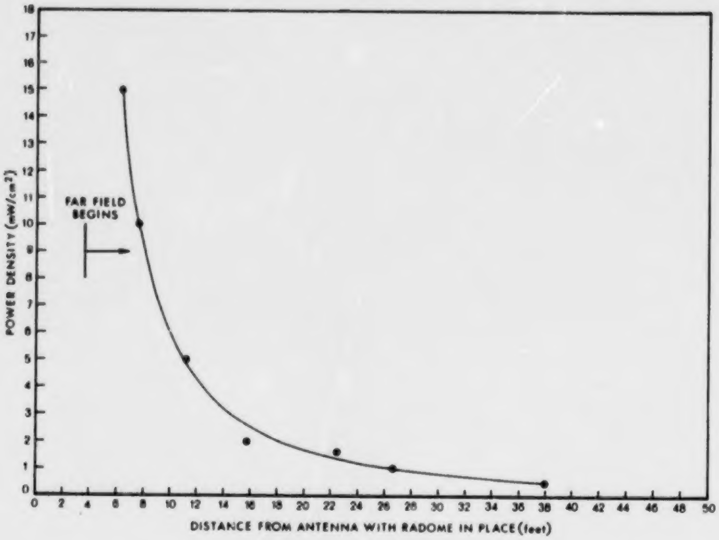


Figure 16. Measurements of Collins WP–103 in Sabre Liner

Table 7. Summary of exposures from radars

Radar configuration	Approximate distance (feet) to exposure of:	
	10 mW/cm^3	1 mW/cm^3
RDR–1B (simulation lab)	9	34
AVQ–10 (simulation lab)	12	47
AVQ–10 (Convair)	18	50+
WP–103 (Sabre Liner)	8	27

for each of the respective radar configurations. From the data, it appears that exposures in the neighborhood of 10 mW/cm^2 may occur in the general range of 8 to 18 feet from the antenna, dependent on the particular radar and conditions under which it might be measured (ground reflections included, radome losses, etc.).

Measurement of the Convair 600 nose cone radome showed an attenuation of approximately 5.5 dB or a power reduction factor of 0.28.

When measurements were made about the perimeter of the simulation lab radome, no detectable radiation lobes were apparent at the 0.2 mW/cm^2 level for either the RDR-1B or the AVQ-10. When approaching the transmitting dish at extremely close-in distances inside the radome, some low-level fields were observed at about 2 feet from the side of the dish.

A survey of the cockpit area of both the Sabre Liner and Convair 600 also showed that no detectable radiation at the 0.2 mW/cm^2 level was present (0.2 mW/cm^2 is the minimum detection capability of the Narda instrument). This was not surprising in the case of the Convair since a good shielding effect was produced by the fuselage shell between the cockpit and the radar antenna. With the Convair, the worst possible antenna position was used for these measurements—it was positioned directly toward the cockpit. Other directions were tried to see if reflections might occur from the wing or propeller structures on the aircraft causing scattering into the cockpit. Again, nothing detectable was observed in the cockpit (including ground reflection, radome losses, etc). However, when the probe was held at arm's length out of the pilot's window (left-hand side) some minimal upscale reading was observed (something slightly greater than 0.2 mW/cm^2).

In similar measurements on the Sabre Liner, no detectable levels were found in the cockpit.

In this case, however, the radar dish is sector scanned and limited to principally the front 270° of view.

Conclusions

On the basis of this study, the following conclusions have been reached:

a. Typical maximum power for aircraft radars lies in the range 20 to 100 kW peak and 20 to 120 W average power.

b. Antenna gains are normally in the range of 25 to 30 dB.

c. Peak ERP is in the range of 6 MW to 100 MW while average ERP is in the range of 6 kW to 120 kW.

d. Exposures to power densities of 10 mW/cm^2 can occur in the range of 8 to 18 feet from the antenna.

e. Aircraft radomes can exhibit attenuations of about 5.5 dB.

f. No radiation levels in excess of 0.2 mW/cm^2 existed in the aircraft cockpits.

g. Normally, airborne radar antennas are rotating devices with either sector scanned or full 360 degree rotation at approximately 15 r/min.

h. In general, the radar beams on commercial aircraft are above 6 feet in height from the ground.

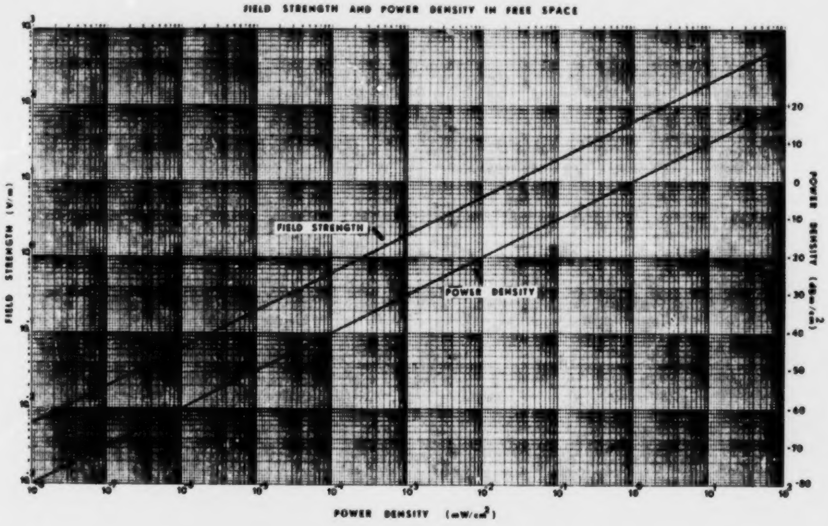
i. Reliable survey data can be obtained only by stopping the antenna rotation.

j. Reflections from nearby objects, including the ground, tend to cause irregularities in the field structure. Because of the unknown phase characteristics of the reflected waves, actual measurements are preferable to determine exposure in these situations.

k. Use of far field antenna gain was not reliable for predicting distances to the 10 mW/cm^2 exposure level.

Recommendations

Further investigation with respect to this study which could add useful information to the question of human exposure from airborne radar would be a determination of possible passenger exposure distances which can be found at airports. This information would prove interesting from the standpoint of an inadvertent exposure occurring when the airplane is parked near areas with passenger waiting rooms. Under such circumstances and depending upon the exact plane-waiting room configuration, potential short-burst radiation levels could be reasonably high. Assuming an instantaneous time average exposure of 5 mW/cm^2, the peak power density could be about 5 W/cm^2.



APPENDIX A. Field strength and power density in free space

VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO	VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO
1.0000	1.0000	0.00	1.0000	1.0000	.5129	.2630	5.8	1.950	3.802
.9988	.9977	0.01	1.0012	1.0023	.5070	.2570	5.9	1.972	3.890
.9977	.9954	0.02	1.0023	1.0046	.5012	.2512	6.0	1.995	3.931
.9966	.9931	0.03	1.0035	1.0069	.4955	.2455	6.1	2.018	4.074
.9954	.9908	0.04	1.0046	1.0093	.4898	.2399	6.2	2.042	4.169
.9943	.9886	0.05	1.0058	1.0116	.4842	.2344	6.3	2.065	4.266
.9931	.9863	0.06	1.0069	1.0139	.4786	.2291	6.4	2.089	4.365
.9920	.9840	0.07	1.0081	1.0162	.4732	.2239	6.5	2.113	4.467
.9908	.9817	0.08	1.0093	1.0186	.4677	.2188	5.6	2.138	4.571
.9897	.9795	0.09	1.0104	1.0209	.4624	.2138	6.7	2.163	4.677
.9886	.9772	0.1	1.012	1.023	.4571	.2089	6.8	2.188	4.786
.9772	.9550	0.2	1.023	1.047	.4519	.2042	6.9	2.213	4.898
.9661	.9333	0.3	1.035	1.072	.4467	.1995	7.0	2.239	5.012
.9550	.9120	0.4	1.047	1.096	.4416	.1950	7.1	2.265	5.129
.9441	.8913	0.5	1.059	1.122	.4365	.1905	7.2	2.291	5.248
.9333	.8710	0.6	1.072	1.148	.4315	.1862	7.3	2.317	5.370
.9226	.8511	0.7	1.084	1.175	.4266	.1820	7.4	2.344	5.495
.9120	.8318	0.8	1.096	1.202	.4217	.1778	7.5	2.371	5.623
.9016	.8128	0.9	1.109	1.230	.4169	.1738	7.6	2.399	5.754
.8913	.7943	1.0	1.122	1.259	.4121	.1698	7.7	2.427	5.888
.8810	.7762	1.1	1.135	1.288	.4074	.1660	7.8	2.455	6.026
.8710	.7586	1.2	1.148	1.318	.4027	.1622	7.9	2.483	6.166
.8610	.7413	1.3	1.161	1.349	.3981	.1585	8.0	2.512	6.310
.8511	.7244	1.4	1.175	1.380	.3936	.1549	8.1	2.541	6.457
.8414	.7079	1.5	1.189	1.413	.3890	.1514	8.2	2.570	6.607
.8318	.6918	1.6	1.202	1.445	.3846	.1479	8.3	2.600	6.761
.8222	.6761	1.7	1.216	1.479	.3802	.1445	8.4	2.630	6.918
.8128	.6607	1.8	1.230	1.514	.3758	.1413	8.5	2.661	7.079
.8035	.6457	1.9	1.245	1.549	.3715	.1380	8.6	2.692	7.244
.7943	.6310	2.0	1.259	1.585	.3673	.1349	8.7	2.723	7.413
.7852	.6166	2.1	1.274	1.622	.3631	.1318	8.8	2.754	7.586
.7762	.6026	2.2	1.288	1.660	.3589	.1288	8.9	2.786	7.762
.7674	.5888	2.3	1.303	1.698	.3548	.1259	9.0	2.818	7.943
.7586	.5754	2.4	1.318	1.738	.3508	.1230	9.1	2.851	8.128
.7499	.5623	2.5	1.334	1.778	.3467	.1202	9.2	2.884	8.318
.7413	.5495	2.6	1.349	1.820	.3428	.1175	9.3	2.917	8.511
.7328	.5370	2.7	1.365	1.862	.3388	.1148	9.4	2.951	8.710
.7244	.5248	2.8	1.380	1.905	.3350	.1122	9.5	2.985	8.913
.7161	.5129	2.9	1.396	1.950	.3311	.1096	9.6	3.020	9.120
.7079	.5012	3.0	1.413	1.995	.3273	.1072	9.7	3.055	9.333
.6998	.4898	3.1	1.429	2.042	.3236	.1047	9.8	3.090	9.550
.6918	.4786	3.2	1.445	2.089	.3199	.1023	9.9	3.126	9.772
.6839	.4677	3.3	1.462	2.138	.3162	.1000	10.0	3.162	10.000
.6761	.4571	3.4	1.479	2.188	.2985	.08913	10.5	3.350	11.22
.6683	.4467	3.5	1.496	2.239	.2818	.07943	11.0	3.548	12.59
.6607	.4365	3.6	1.514	2.291	.2661	.07079	11.5	3.758	14.13
.6531	.4266	3.7	1.531	2.344	.2512	.06310	12.0	3.981	15.85
.6457	.4169	3.8	1.549	2.399	.2371	.05623	12.5	4.217	17.78
.6383	.4074	3.9	1.567	2.455	.2239	.05012	13.0	4.467	19.95
.6310	.3981	4.0	1.585	2.512	.2113	.04467	13.5	4.732	22.39
.6237	.3890	4.1	1.603	2.570	.1995	.03981	14.0	5.012	25.12
.6166	.3802	4.2	1.622	2.630	.1884	.03548	14.5	5.309	28.18
.6095	.3715	4.3	1.641	2.692	.1778	.03162	15.0	5.623	31.62
.6026	.3631	4.4	1.660	2.754	.1585	.02512	16.0	6.310	39.81
.5957	.3548	4.5	1.679	2.818	.1413	.01995	17.0	7.079	50.12
.5888	.3467	4.6	1.698	2.884	.1259	.01585	18.0	7.943	63.10
.5821	.3388	4.7	1.718	2.951	.1122	.01259	19.0	8.913	79.43
.5754	.3311	4.8	1.738	3.020	.1000	.01000	20.0	10.000	100.00
.5689	.3236	4.9	1.758	3.090	.03162	.00100	30.0	31.620	1,000.00
.5623	.3162	5.0	1.778	3.162	.01	.00010	40.0	100.00	10,000.00
.5559	.3090	5.1	1.799	3.236	.003162	.00001	50.0	316.20	10^5
.5495	.3020	5.2	1.820	3.311	.001	10^{-6}	60.0	1,000.00	10^6
.5433	.2951	5.3	1.841	3.388	.0003162	10^{-7}	70.0	3,162.00	10^7
.5370	.2884	5.4	1.862	3.467	.0001	10^{-8}	80.0	10,000.00	10^8
.5309	.2818	5.5	1.884	3.548	.00003162	10^{-9}	90.0	31,620.00	10^9
.5248	.2754	5.6	1.905	3.631	10^{-5}	10^{-10}	100.0	10^5	10^{10}
.5188	.2692	5.7	1.928	3.715					

Figure 15. APPENDIX B. Voltage and power ratios to dB

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Acknowledgements

The authors are especially grateful to the FAA staff who assisted in this field trip: Dr. Robert N. Thompson and Mr. Jim D. Langwell of the Industrial Hygiene Section in the Civil Aeromedical Institute for their excellent cooperation and coordination of facilities and personnel involved in this measurement study; Mr. Harold K. Harvell, Chief of the Aircraft and Avionics Maintenance Branch, Aircraft Services Base, for his help in making arrangements for access to aircraft and the radar simulation lab; Mr. Alvin E. Kounovsky and Mr. George F. Bonner in the Avionics Maintenance Section, for their instruction and assistance in the operation of laboratory radar equipment; Mr. Jim L. McCloskey and Mr. John E. Burleson in the Avionics Maintenance Section for their patience and assistance in setup and operation of radars mounted in the airplanes.

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, November 1973

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

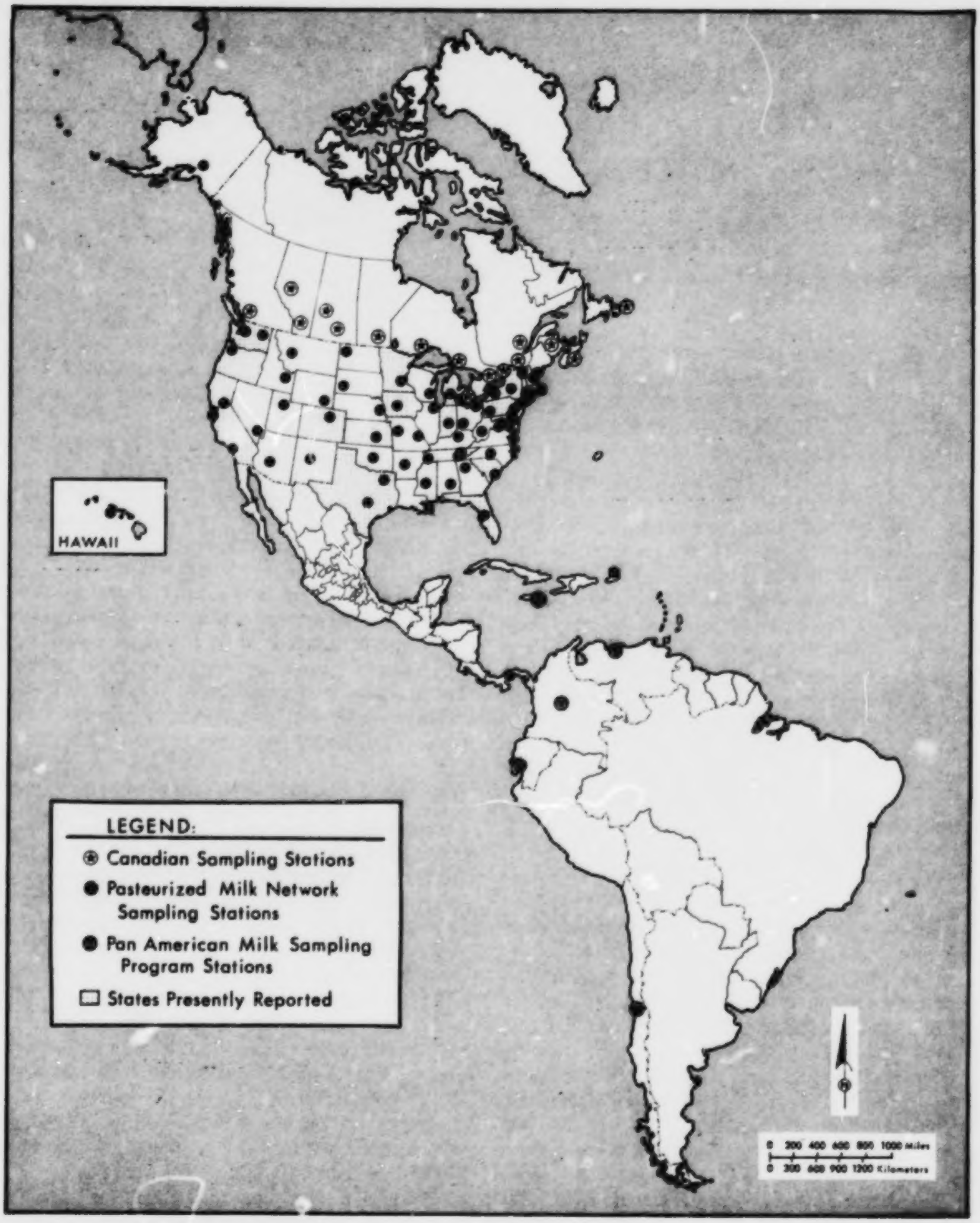
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
● Pan American Milk Sampling Program Stations
☐ States Presently Reported
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers

Figure 1. Milk sampling networks in the Western Hemisphere

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metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Research and Development conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≧50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≧20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≧100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports*.

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the

Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period December 1972 through November 1973

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	5	0	4
Alaska:	Palmer[c]	P	NA	4	0	1
Ariz:	Phoenix[c]	P	NA	0	0	0
Ark:	Little Rock[c]	P	NS	9	NS	1
Calif:	Los Angeles[c]	P	NA	0	0	0
	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	0	0	0
	Del Norte	P	11	10	0	6
	Fresno	P	0	1	0	2
	Humboldt	P	2	3	0	1
	Los Angeles	P	0	1	0	1
	Mendocino	P	2	2	0	3
	Sacramento	P	0	2	0	2
	San Diego	P	0	1	0	2
	Santa Clara	P	0	2	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	0	2	0	2
Colo:	Denver[c]	P	NS	3	NS	0
	East	R	NS		NS	22
	Northeast	R	NS		NS	0
	Northwest	R	NA		[d]0 (3)	2
	South Central	R	NS		NS	NS
	Southeast	R	NS		NS	0
	Southwest	R	NA		[d]0	0
	West	R	NA		[d]0	0
Conn:	Hartford[c]	P	NA	4	0	4
	Central	P	NA		0	0
Del:	Wilmington[c]	P	NA	5	0	2
D.C:	Washington[c]	P	NA	3	0	1
Fla:	Tampa[c]	P	NA	4	22	27
	Central	R	5	6	21	28
	North	R	4	6	24	14
	Northeast	R	6	6	11	31
	Southeast	R	6	5	32	49
	Tampa Bay area	P	5	5	31	29
	West	R	8	8	28	9
Ga:	Atlanta[c]	P	NA	4	0	5
Hawaii:	Honolulu[c]	P	NA	0	0	0
Idaho:	Idaho Falls[c]	P	NA	3	0	0
Ill:	Chicago[c]	P	NA	5	0	1
Ind:	Indianapolis[c]	P	NA	4	0	2
	Central	P	5	6	10	7
	Northeast	P	6	5	10	9
	Northwest	P	7	7	0	8
	Southeast	P	6	6	0	7
	Southwest	P	6	7	0	8
Iowa:	Des Moines[c]	P	NA	4	0	0
	Des Moines	P	4	5	0 (3)	0
	Iowa City	P	NS	5	NS	0
	LeMars	P	4	4	NS	2
	Little Cedar	P	6	6	0	0
Kans:	Wichita[c]	P	NA	5	11	1
	Coffeyville	P	6	7	0	7
	Dodge City	P	3	5	0	6
	Falls City, Nebr	P	5	6	0	5
	Hays	P	5	7	0	5
	Kansas City	P	NS	5	NS	7
	Topeka	P	8	8	0	5
	Wichita	P	7	7	3	6
Ky:	Louisville[c]	P	NA	5	0	2
La:	New Orleans[c]	P	NS	8	NS	1
Maine:	Portland[c]	P	NA	5	12	16
Md:	Baltimore[c]	P	NA	6	0	3
Mass:	Boston[c]	P	NA	7	0	12
Mich:	Detroit[c]	P	NA	6	15	3
	Grand Rapids[c]	P	NA	7	0	1
	Bay City	P	NA	8	12	1
	Charlevoix	P	NA	8	0	2
	Detroit	P	NA	6	0	0
	Grand Rapids	P	NA	8	0	2
	Lansing	P	NA	9	0	3
	Marquette	P	NA	9	0 (2)	8
	Monroe	P	NA	11	0 (2)	1
	South Haven	P	NA	11	0 (3)	3
Minn:	Minneapolis[c]	P	NA	7	0	2
	Bemidji	P	NA	7	0	11
	Duluth	P	NA	16	0	18
	Fergus Falls	P	NA	7	0	0
	Little Falls	P	NA	18	0	26
	Mankato	P	NA	5	0	0
	Marshall	P	NA	4	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period, December 1972 through November 1973—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
Minn:	Minneapolis	P	NA	16	0	0
	Rochester	P	NA	6	0	0
Miss:	Jackson[e]	P	NA	8	0	6
Mo:	Kansas City[e]	P	NA	4	0	0
	St. Louis[e]	P	NA	7	0	1
Mont:	Helena[e]	P	NA	2	0	0
Nebr:	Omaha[e]	P	NA	3	0	0
Nev:	Las Vegas[e]	P	NS	4	NS	0
N.H:	Manchester[e]	P	NA	8	14	9
N.J:	Trenton[e]	P	NA	5	0	3
N. Mex:	Albuquerque[e]	P	NA	0	0	0
N.Y:	Buffalo[e]	P	NA	4	0	3
	New York City[e]	P	NA	5	0	3
	Syracuse[e]	P	NA	6	0	1
	Albany	P	5	4	0	0
	Buffalo	P	NA	4	26	0
	Massena	P	NA	6	16	0
	New York City	P	NA	7	0	0
	Syracuse	P	NA	5	0	6
N.C:	Charlotte[e]	P	NA	7	0	5
N. Dak:	Minot[e]	P	NA	7	0	0
Ohio:	Cincinnati[e]	P	NA	5	20	3
	Cleveland[e]	P	NA	6	0	2
Okla:	Oklahoma City[e]	P	NA	3	0	0
Oreg:	Portland[e]	P	NA	3	0	1
	Baker	P	NA		[d]0	1
	Coos Bay	P	NA		[d]0	4
	Eugene	P	NA		[d]0	0
	Medford	P	NA		[d]0	1
	Portland composite	P	NA		[d]0	0
	Portland local	P	NA		[d]0	2
	Redmond	P	NA		[d]0	1
	Tillamook	P	NA		[d]0	8
Pa:	Philadelphia	P	NA	5	0	2
	Pittsburgh[e]	P	NA	8	0	4
	Dauphin	P	4	4	0	0
	Erie	P	8	6	0	0
	Philadelphia	P	3	3	0	1
	Pittsburgh	P	4	5	0	0
R.I:	Providence[e]	P	NA	5	0	6
S.C:	Charleston[e]	P	NA	6	0	5
	Chapin	R	NS	8	NS	11
	Clemson	R	NS	8	NS	7
	Columbia	R	8	8	6	9
	Fairfield	R	NS	7	NS	13
	Hartsville-02	R	6	7	9	12
	Hartsville-03	R	NS	16	NS	15
	Lee County	R	8	7	8	16
	Oconee County	R	NS	8	NS	8
	Pickens	R	NS	7	NS	6
	Williston	R	NS	7	NS	15
	Winnsboro	R	NS	7	NS	16
S. Dak:	Rapid City[e]	P	NA	5	0	1
Tenn:	Chattanooga[e]	P	NA	6	0	2
	Knoxville[e]	P	NA	0	0	0
	Memphis[e]	P	NA	8	0	2
	Chattanooga	P	7	8	0	3
	Clinton	R	8	4	11	4
	Fayetteville	R	8	7	0	3
	Kingston	R	9	6	0	0
	Knoxville	P	5	3	0	2
	Lawrenceburg	R	NS	6	NS	6
	Nashville	P	NS	3	NS	0
	Pulaski	R	0	6	0	0
	Sequoyah	R	NS	9	NS	0
Tex:	Austin[e]	P	NA	0	0	0
	Dallas[e]	P	NA	3	0	0
Utah:	Salt Lake City[e]	P	NA	2	0	1
Vt:	Burlington[e]	P	NA	4	16	6
Va:	Norfolk[e]	P	NA	6	0	2
Wash:	Seattle[e]	P	NA	2	0	0
	Spokane[e]	P	NA	5	0	0
	Benton County	R	0	1	0	0
	Franklin County	R	NS	1	NS	0
	Longview	R	6	4	0	3
	Sandpoint, Idaho	R	3	6	12	1
	Skagit County	R	7	4	0	0
W. Va:	Charleston[e]	P	NA	6	0	2
Wisc:	Milwaukee[e]	P	NA	4	0	1
Wyo:	Laramie[e]	P	NA	1	0	1

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for November 1973 and 12-month period December 1972 through November 1973—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:						
Alberta:	Calgary	P	NA		0	9
	Edmonton	P	NA		0	13
British Columbia:	Vancouver	P	NA		0	13
Manitoba:	Winnipeg	P	NA		10	10
New Brunswick:	Moncton	P	NA		0	9
Newfoundland:	St. John's	P	NA		13	16
Nova Scotia:	Halifax	P	NA		0	11
Ontario:	Ottawa	P	NA		0	6
	Sault Ste. Marie	P	NA		14	16
	Thunder Bay	P	NA		0	12
	Toronto	P	NA		0	7
	Windsor	P	NA		0	6
Quebec:	Montreal	P	NA		0	7
	Quebec	P	NA		10	13
Saskatchewan:	Regina	P	NA		0	8
	Saskatoon	P	NA		0	8
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	0	NS	11
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	9	1	0	0
Jamaica:	Mandeville	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	2	0	2
Venezuella:	Caracas	P	0	1	0	2
PMN network average[e]			0	4	2	3

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for

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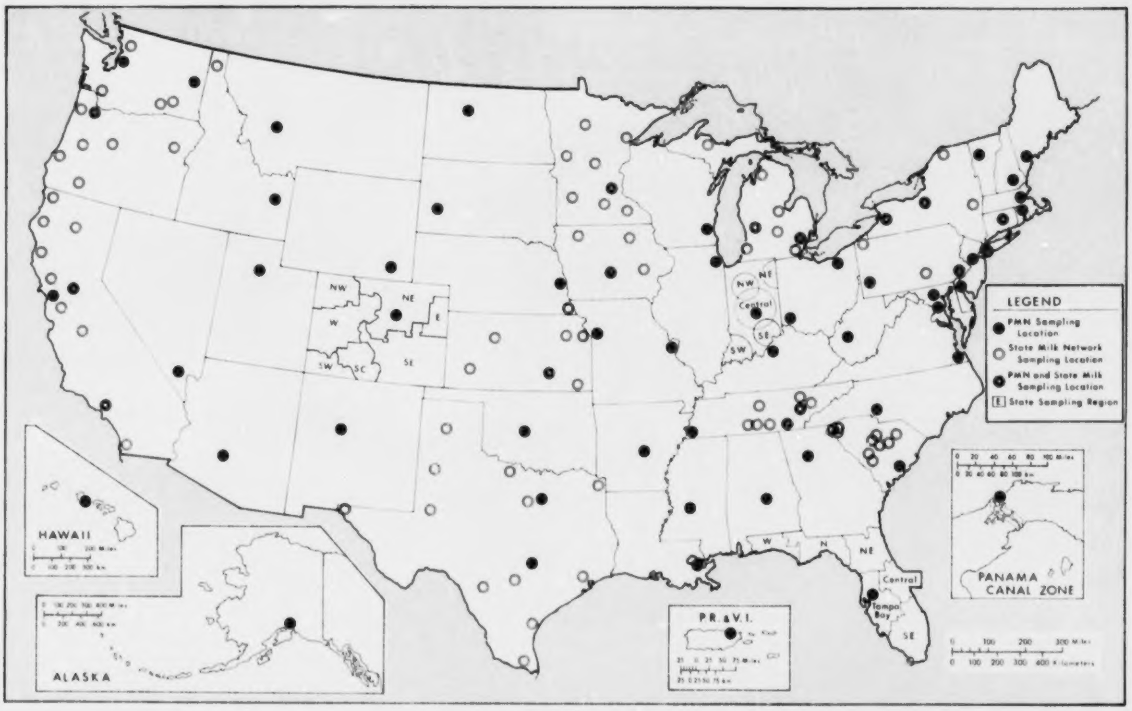
LEGEND
PMN Sampling Location
State Milk Network Sampling Location
PMN and State Milk Sampling Location
E State Sampling Region
NW
NE
W
E
SW
SC
SE
Central
N
Tampa Bay
HAWAII
ALASKA
P.R. & V.I.
PANAMA CANAL ZONE

Figure 2. State and PMN milk sampling stations in the United States

strontium-90 and cesium-137 for November 1973 and the 12-month period, December 1972 to November 1973. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for November 1973 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 11 pCi/liter in the United States for November 1973 and the highest 12-month average was 18 pCi/liter (Little Falls, Minn.) representing 9.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 32 pCi/liter in the United States for November 1973, and the highest 12-month average was 49 pCi/liter (Southeast Florida) representing 1.4 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

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(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER, and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1969).

(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine–131, cesium–137, strontium–89, and strontium–90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Institutional Diet	April–June 1973	March 1974
Strontium-90 in Tri-City Diets	1972	December 1973

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1969	January 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1971–June 1972	March 1974
New York	July–December 1971	August 1973
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Tritium Surveillance System	April–June 1973	October 1973
Washington	July 1970–June 1971	August 1973

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Florida Waters, 1970[1]

Radiological and Occupational Health Section
Florida State Division of Health

The Florida State Division of Health samples raw surface, ground, and treated water in 13 hydrological subbasins as shown in figure 1. Samples collected on a variable frequency and analyzed for gross alpha and beta radioactivity during 1970 are presented in table 1.

In addition to sampling being done by the Florida State Division of Health, the Bioenvironmental Engineering Research Laboratory, University of Florida, samples surface, ground, and municipal water in Alachua County for gross beta radioactivity. Samples are taken monthly from each sampling point with the exception of the City of Gainesville where raw water is sampled daily. These data for 1970 are summarized in table 2. Gross beta radioactivity above the minimum reported concentration was detected in 6 water samples taken in Alachua

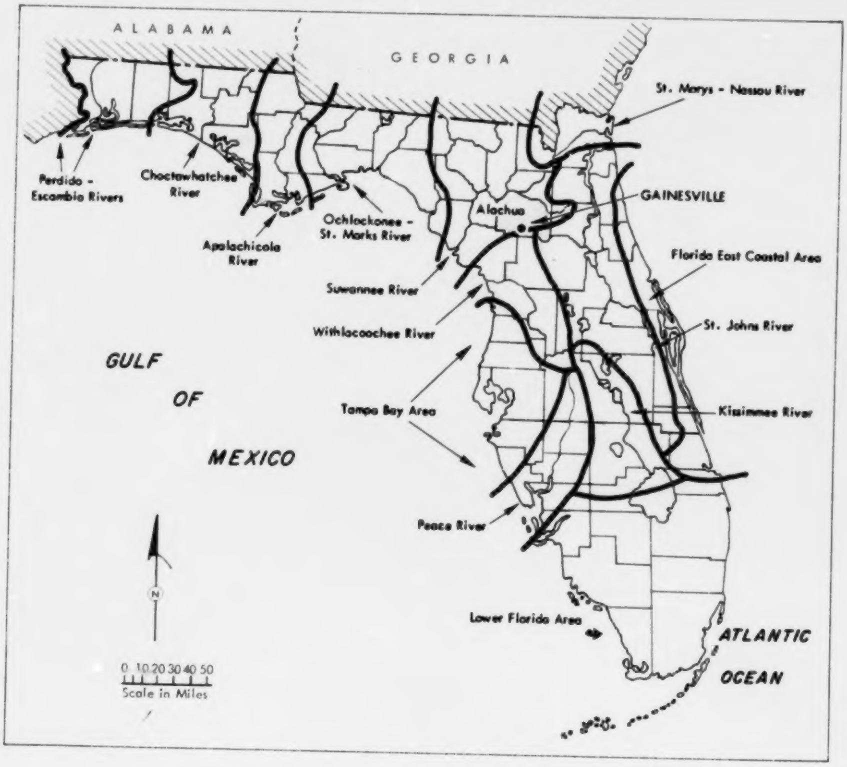
ALABAMA
GEORGIA
St. Marys - Nassau River
Perdido - Escambia Rivers
Choctawhatchee River
GAINESVILLE
Alachua
Ochlockonee - St. Marks River
Apalachicola River
Florida East Coastal Area
Suwannee River
Withlacoochee River
St. Johns River
GULF
OF
MEXICO
Tampa Bay Area
Kissimmee River
Peace River
N
Lower Florida Area
ATLANTIC
OCEAN
0 10 20 30 40 50
Scale in Miles

Figure 1. Hydrological surface subbasins in Florida

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[1] Data taken from "Report of Florida Radiological Surveillance Programs, 1970," Bureau of Preventable Diseases, Radiological and Occupational Health Section, Jacksonville, Fla.

County. The 6 samples averaged 13 pCi/liter of gross beta radioactivity.

During 1970, only 18 samples out of a total of 68 collected from 45 sampling sites showed gross beta radioactivity greater than the minimum reported concentration. The 18 surface, ground, and municipal water samples averaged 18 pCi/liter. The average gross beta radioactivity in water samples is well below the limitations imposed by the standard for gross beta radioactivity in drinking water (1 000 pCi/liter) (*1*).

Table 1. Gross alpha and beta radioactivity in Florida water, 1970

Location	Number of samples	Alpha (pCi/liter)	Beta (pCi/liter)
St. John's River:			
Raw	15	<7	<10
	1	<7	20
Treated	6	<7	<10
Sewage treatment plants	•3	<7	<10
	1	<7	16
	1	<7	20
St. Mary's, Nassau, and Amelia Rivers:			
Raw	1	<7	17
	2	<7	<10
Lower Florida area:			
Raw	1	<7	14
	1	<7	10
	1	<7	<10
Treated	7	<7	<10
Sewage treatment plant	•2	<7	38
	•2	<7	22
	•1	<7	18
	•1	<7	14
	•1	<7	12
	•1	<7	11
	•5	<7	<10
Florida East Coastal area:			
Raw	1	<7	<10
Treated	3	<7	<10
Kissimmee River Basin:			
Treated	1	<7	12
Sewage treatment plant	•2	<7	<10
Peace River:			
Treated	1	<7	<10
Tampa Bay area:			
Raw	1	<7	<10
Sewage treatment plants	•1	<7	18
	•1	<7	11
	•2	<7	<10
Withlacoochee and Waccasassa Rivers:			
Treated	2	<7	<10

• Composite sample

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Public Health Service Drinking Water Standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Table 2. Gross beta radioactivity in Florida water, 1970

Location	Radioactivity concentration (pCi/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Summary
Alachua County: (18 sampling locations)													
Maximum	19.0	13.10	5.48	—	—	—	13.10	—	—	11.40	—	—	19.0
Average	3.25	5.65	1.90	NS	NS	NS	4.70	NS	NS	4.46	NS	NS	3.99
City of Gainesville:													
Maximum	8.84	10.5	10.1	7.59	2.95	7.58	5.9	3.79	NS	10.90	6.32	7.58	10.90
Average	2.53	4.24	2.62	2.82	1.5	3.79	2.02	1.85	—	5.04	2.86	4.07	3.03

NS, no sample collected.

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Pan American Health Organization and the California Department of Health.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports*.

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Mexican air monitoring program	January–December 1973	December 1973
Plutonium in airborne particulates	October–December 1972	June 1973
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network
November 1973

Eastern Environmental Radiation Facility,
Montgomery
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which gathers samples at 68 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during November 1973.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

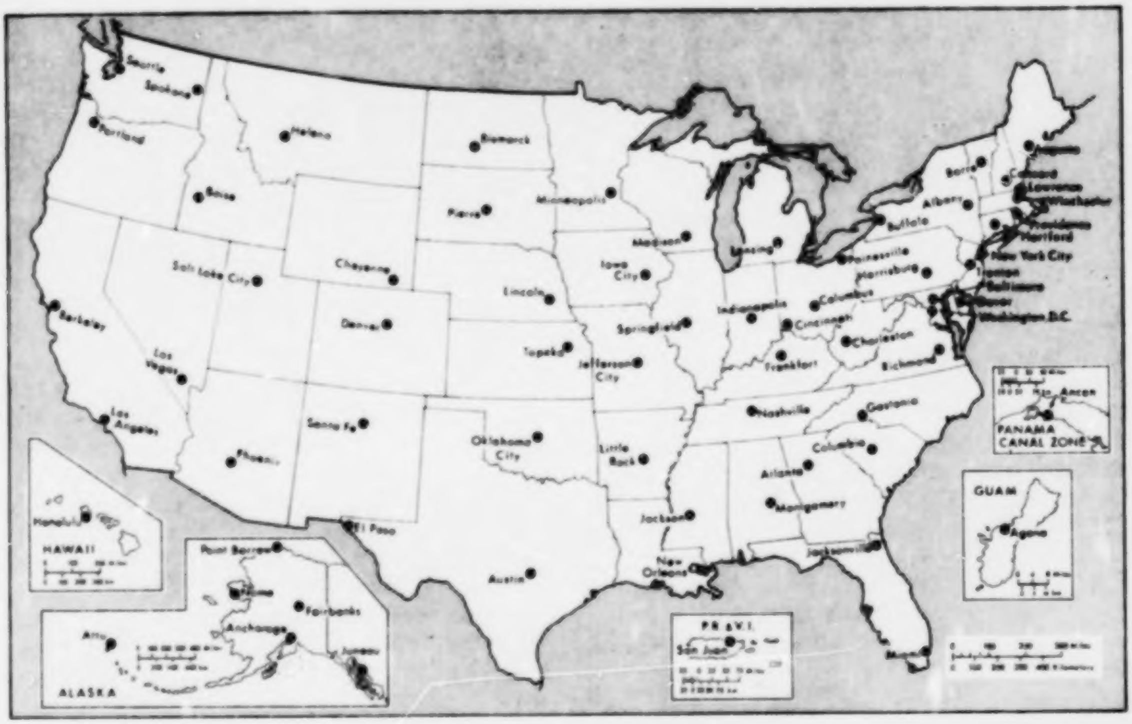
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Salt Lake City
Cheyenne
Lincoln
Iowa City
Lansing
Buffalo
Albany
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
New York City
Trenton
Baltimore
Dover
Washington D.C.
Painesville
Harrisburg
Columbus
Indianapolis
Cincinnati
Charleston
Frankfort
Richmond
Springfield
Jefferson City
Topeka
Denver
Berkeley
Las Vegas
Los Angeles
Phoenix
Santa Fe
Oklahoma City
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Jackson
New Orleans
Jacksonville
Miami
Austin
El Paso
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Attu
Juneau
ALASKA
P.R. & V.I.
San Juan
GUAM
Agana
Ancon
PANAMA CANAL ZONE

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, November 1973

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	9	1	0	1	0.03	<0.01	0.02	93	<0.1
Calif:	Berkeley	9	0	0	0	.02	<.01	<.01	37	<.04
	Los Angeles	9	1	0	1	.04	.01	.02		
Colo:	Denver	9	2	0	1	.08	.02	.04	3	.03
Ind:	Indianapolis	19	2	0	0	.01	.01	.02		
Nev:	Las Vegas	9	2	0	1	.04	.02	.03		
N. Mex:	Sante Fe	0								
N.Y:	Buffalo	9	1	0	0	.03	.01	.02	3	.01
N. Dak:	Bismarck	9	2	0	1	.04	.01	.03	10	.05
Ohio:	Columbus	4	1	0	1	.06	.02	.03		
Okla:	Oklahoma City	0								
Oreg:	Portland	20	0	0	0	.02	<.01	.01		
Pa:	Harrisburg	18	2	0	1	.05	<.01	.02		
S.C:	Columbia	7	1	0	1	.04	.02	.03	5	.04
Network summary		131	2	0	1	0.08	<0.01	0.03	25	0.02

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network
November 1973

National Environmental Research Center—
Las Vegas[1]
Environmental Protection Agency

The Air Surveillance Network (ASN),[2] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports.*

Results

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to 1 significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to 2 significant figures. For averaging purposes individual concentration values less than the minimum detectable concentration (~0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

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[1] Formerly the Western Environmental Research Laboratory.

[2] The ASN is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

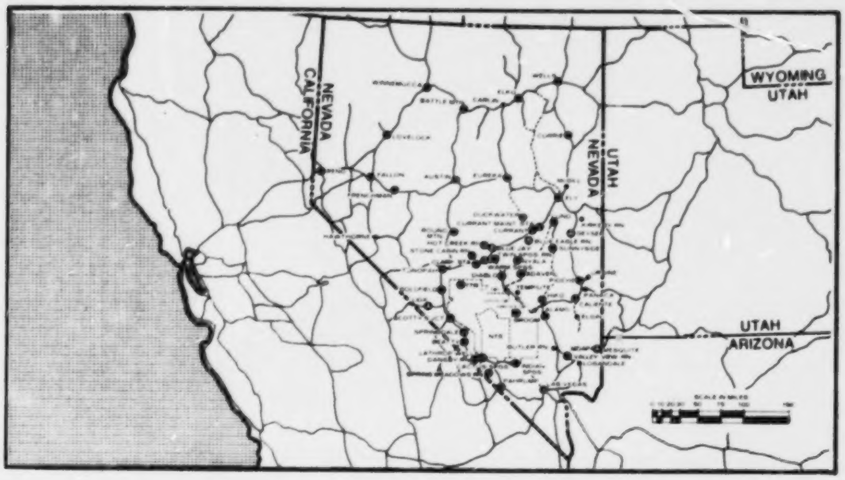
NEVADA
CALIFORNIA
UTAH
NEVADA
WYOMING
UTAH
UTAH
ARIZONA
SCALE IN MILES

Figure 2. NERC–LV Air Surveillance Network stations in Nevada

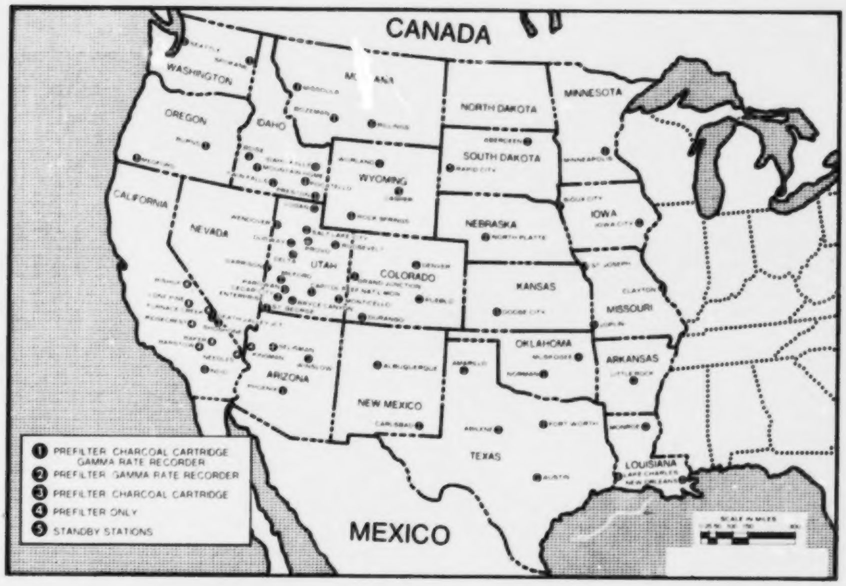
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
NEBRASKA
IOWA
UTAH
COLORADO
KANSAS
MISSOURI
ARIZONA
OKLAHOMA
ARKANSAS
NEW MEXICO
TEXAS
LOUISIANA
MEXICO
SCALE IN MILES
❶ PREFILTER CHARCOAL CARTRIDGE GAMMA RATE RECORDER
❷ PREFILTER GAMMA RATE RECORDER
❸ PREFILTER CHARCOAL CARTRIDGE
❹ PREFILTER ONLY
❺ STANDBY STATIONS

Figure 3. NERC–LV Air Surveillance Network stations outside Nevada

Concentration (pCi/m³)	Reported value of concentration above MDC (pCi/m³)	Reported value of concentration below MDC (pCi/m³)
<0.05	<0.1	<0.1
≧0.05 <0.15	0.1	<0.1
≧0.15	As calculated and rounded	<calculated MDC

As shown in table 1, the highest gross beta concentration at continuously operated stations within the network was 0.3 pCi/m³ at Blue Jay, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during November 1973.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, November 1973

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average
Ariz:	Kingman	20	0.1	<0.1	0.1
	Seligman	13	.1	<.1	.1
Calif:	Baker	13	.1	<.1	.1
	Barstow	14	.1	<.1	<.1
	Bishop	13	.1	<.1	.1
	Death Valley Junction	14	.1	<.1	.1
	Furnace Creek	13	.1	<.1	.1
	Lone Pine	9	.1	<.1	<.1
	Needles	12	.1	<.1	.1
	Ridgecrest	13	.1	<.1	<.1
	Shoshone	13	.1	<.1	<.1
Nev:	Alamo	13	.1	<.1	.1
	Austin	11	.1	<.1	<.1
	Beatty	13	.1	<.1	<.1
	Blue Eagle Ranch (Currant)	13	.1	<.1	<.1
	Blue Jay	13	.3	<.1	.1
	Caliente	13	.1	<.1	.1
	Currant Ranch	13	.1	<.1	<.1
	Diablo	13	.1	<.1	<.1
	Duckwater	10	.1	<.1	<.1
	Ely	13	<.1	<.1	<.1
	Eureka	13	.1	<.1	<.1
	Fallini's Twin Springs Ranch	13	.1	<.1	.1
	Geyser Ranch (Pioche)	12	.1	<.1	.1
	Goldfield	13	<.1	<.1	<.1
	Groom Lake	11	.1	<.1	.1
	Hiko	13	.1	<.1	.1
	Indian Springs	13	.1	<.1	<.1
	Las Vegas	18	.1	<.1	.1
	Lathrop Wells	8	.1	<.1	.1
	Lida	13	.1	<.1	<.1
	Lund	12	.1	<.1	<.1
	Mesquite	13	.1	<.1	.1
	Nyala	13	.1	<.1	<.1
	Pahrump	13	.1	<.1	<.1
	Pioche	13	.2	<.1	<.1
	Round Mountain	13	.1	<.1	<.1
	Scotty's Junction	13	.1	<.1	<.1
	Stone Cabin Ranch	13	.1	<.1	<.1
	Sunnyside	14	.2	<.1	<.1
	Tonopah	13	.1	<.1	<.1
	Tonopah Test Range	9	.1	<.1	.1
	Warm Springs	9	.1	<.1	<.1
	Warm Springs Ranch	13	.1	<.1	.1
Utah:	Cedar City	10	.2	<.1	<.1
	Delta	9	.2	<.1	.1
	Garrison	13	.2	<.1	.1
	Milford	11	.1	<.1	<.1
	St. George	13	.2	<.1	.1

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3. Canadian Air and Precipitation Monitoring Program,[3] November 1973

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for November 1973 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, November 1973

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.04	0.01	0.02	12	0.27
Coral Harbour	4	.04	.01	.03	23	.26
Edmonton	4	.04	.02	.03	9	.40
Ft. Churchill	4	.04	.01	.02	3	.21
Fredericton	2	.03	.03	.03	6	.57
Goose Bay	1	.01	.01	.01	4	.38
Halifax	4	.03	.02	.02	8	.53
Inuvik	3	.02	.02	.02	9	.12
Montreal	4	.01	<.01	.01	19	1.20
Moosonee	4	.03	.01	.02	1	.03
Ottawa	3	.02	.01	.01	15	.88
Quebec	3	.02	.01	.01	7	.52
Regina	4	.04	.02	.03	10	.23
Resolute	4	.04	.02	.03	7	.13
St. John's, Nfld	4	.02	.01	.02	NS	NS
Saskatoon	4	.04	.03	.03	6	.23
Sault Ste. Marie	4	.02	.01	.02	9	.70
Thunder Bay	4	.03	.01	.02	11	.95
Toronto	1	.03	.03	.03	18	1.70
Vancouver	4	.01	.01	.01	4	.66
Whitehorse	4	.05	.02	.03	9	.21
Windsor	NS				9	.86
Winnipeg	2	.01	<.01	.01	10	.39
Yellowknife	3	.03	.02	.02	12	.32
Network summary	78	0.05	<0.01	0.02	10	0.51

NS, no sample.

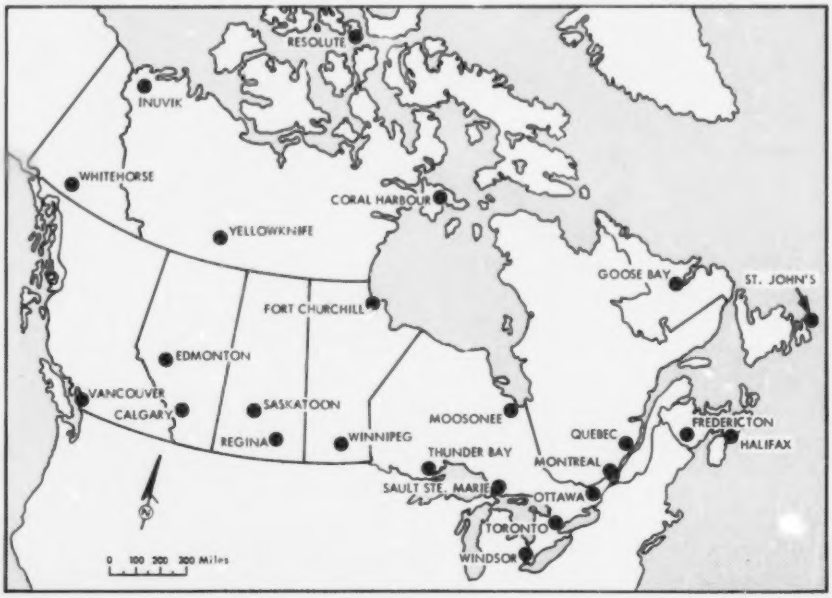
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
N
0 100 200 300 Miles

Figure 4. Canadian air and precipitation sampling stations

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[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

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REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

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4. Pan American Air Sampling Program November 1973

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The November 1973 air monitoring results from the participating countries are given in table 4.

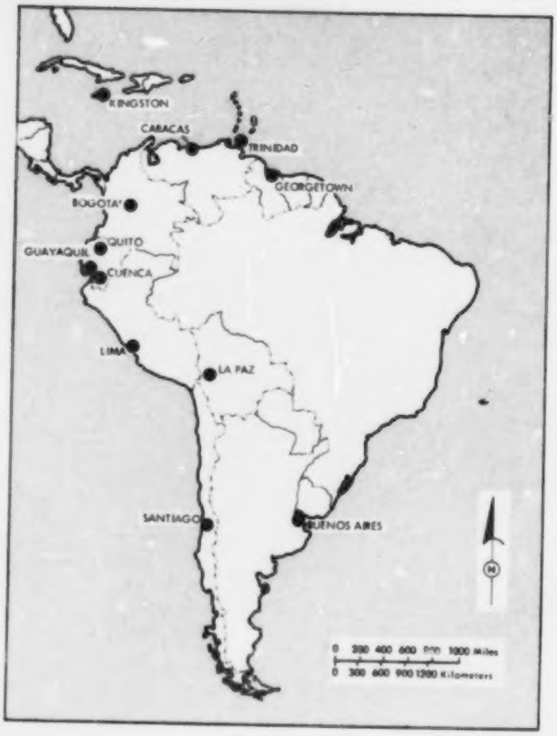

Figure 5. Pan American Air Sampling Program stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, November 1973

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	13	0.01	0.00	0.01
Chile:	Santiago	30	.01	.00	.01
Colombia:	Bogota	21	.00	.00	.00
Ecuador:	Cuenca	5	.02	.00	.01
	Guayaquil	18	.02	.01	.01
	Quito	15	.01	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	0			
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	16	.01	.00	.00
Pan American summary		118	0.02	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period.
Values less than 0.005 pCi/m³ are reported and used in averaging 0.00 pCi/m³.

5. California Air Sampling Program November 1973

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health where they are analyzed for their radioactive content.

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2-cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 5 presents the monthly gross beta radioactivity in air for November. The monthly sample results are presented quarterly.

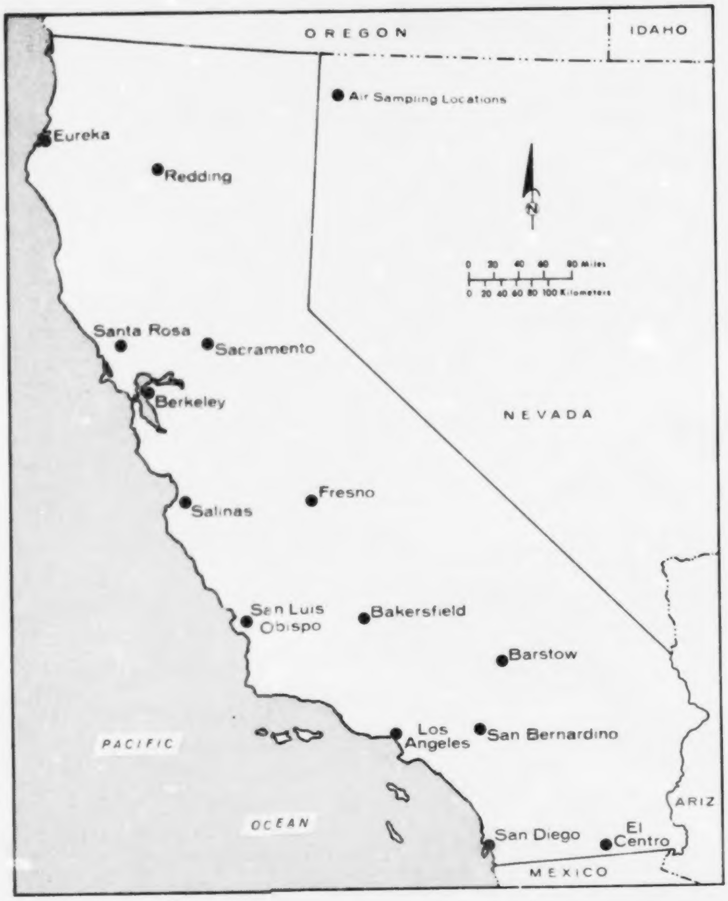
OREGON
IDAHO
● Air Sampling Locations
N
0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Eureka
Redding
Santa Rosa
Sacramento
Berkeley
NEVADA
Salinas
Fresno
San Luis Obispo
Bakersfield
Barstow
Los Angeles
San Bernardino
PACIFIC
OCEAN
ARIZ
San Diego
El Centro
MEXICO

Figure 6. California air sampling program stations

Table 5. Gross beta radioactivity in California air, November 1973

Station location	Number of samples	Gross beta radioactivity (pCi/m^3)		
		Maximum	Minimum	Average
Bakersfield	25	1.05	0.01	0.33
Barstow	30	1.03	.03	.19
Berkeley	28	.37	.00	.05
El Centro	30	.75	.04	.14
Eureka	30	.11	.00	.03
Fresno	30	.68	.02	.18
Los Angeles	30	.18	.00	.07
Redding	30	.14	.01	.07
Sacramento	30	.24	.02	.07
Salinas	30	.66	.02	.18
San Bernardino	30	.60	.02	.14
San Diego	30	.34	.05	.10
San Luis Obispo	30	.34	.00	.08
Santa Rosa	30	.22	.00	.04
Summary	413	1.05	0.00	0.12

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Hanford Atomic Products Operation.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2]
January–December 1970

Battelle Pacific Northwest Laboratories
Richland, Wash.

The primary mission at the Hanford site of the Atomic Energy Commission (AEC) has been the production of plutonium. Activities have included nuclear fuel fabrication, plutonium production and test reactor operation, chemical separations of irradiated fuels, laboratory support and research, waste storage and disposal, and plant support operations. In recent years, privately-owned facilities located within the Hanford site boundaries have included a power generating station, an office building, and a radioactive waste burial site.

Low-level wastes from Hanford operations, fallout from nuclear weapons testing, naturally-occurring radioelements, and cosmic radiation all contribute to radioactivity in the Hanford environs. The most significant Hanford contributions to off-plant radioactivity and consequent population doses have usually originated with reactor cooling water released to the Columbia River (*1–3*). Between December 1964 and December 1970, all but one (KE) of the eight production reactors with once-through cooling were deactivated. The only other production reactor remaining in operation at Hanford during 1970 was N reactor, which has a closed primary cooling loop and releases only minor quantities of radioactivity to the river.

The purpose of this annual report is to present an evaluation of the combined offsite effects of the radioactive effluents released to uncontrolled areas by all Hanford contractors during 1970.

The Hanford site is in a semiarid region of southeastern Washington State (figure 1) where the average rainfall is about 16 cm (6 inches). This section of the State has a

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[2] Summarized from Pacific Northwest Laboratory, "Environmental Surveillance at Hanford for 1970," BNWL-1669 (September 1973).

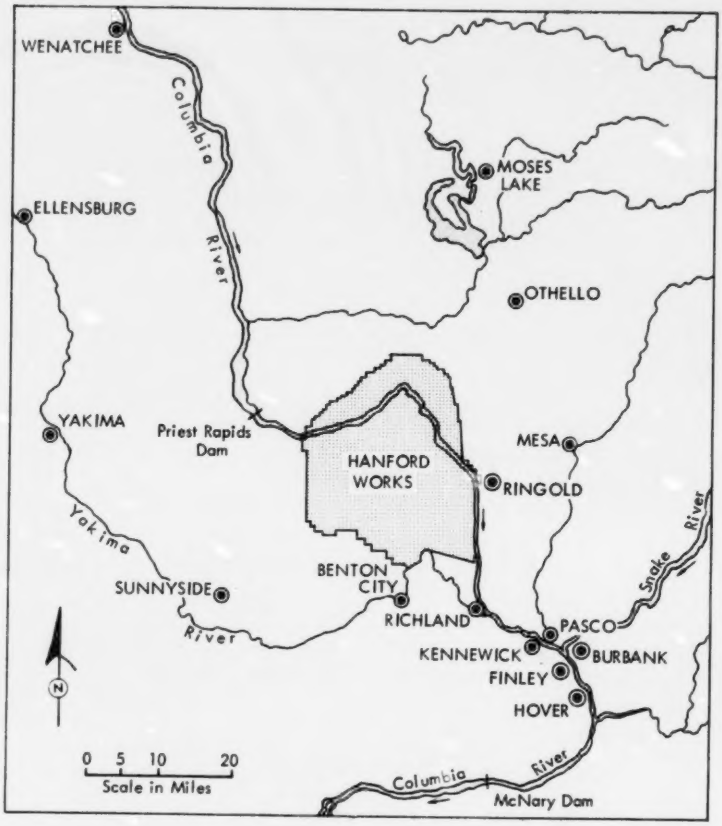
WENATCHEE
Columbia River
ELLENSBURG
MOSES LAKE
OTHELLO
YAKIMA
Priest Rapids Dam
HANFORD WORKS
MESA
RINGOLD
Snake River
Yakima River
SUNNYSIDE
BENTON CITY
RICHLAND
PASCO
KENNEWICK
BURBANK
FINLEY
HOVER
N
0 5 10 20
Scale in Miles
Columbia River
McNary Dam

Figure 1. Hanford project environs

sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site covers an area of about 1300 km^2 (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The nearest population center is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant together with the surrounding agricultural area, is about 100 000.

The farming area closest to Hanford is on Wahluke Slope, about 11 km (7 miles) from N reactor but much of the land east and south of the project boundary is under cultivation. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two

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small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the N reactor. The principal products from the larger farm plots are hay, fruit, beef, and dairy products.

Sources and levels of environmental radioactivity

Radioactive wastes continued to be generated during 1970 by the KE and N production reactors, the chemical processing plants, and the laboratories. High-level wastes were concentrated and retained in storage in the chemical processing areas. Controlled releases of low-level wastes, for which concentration and storage were not feasible, were made to the ground, to the atmosphere, and to the Columbia River.

Changes of significance in plant operations during 1970 included the retirement in February of KW reactor, the seventh of the eight Hanford production reactors using single-pass cooling to be retired since 1964. Two plutonium production reactors, one single-pass (KE) and one recirculating coolant dual-purpose reactor (N), remained in operation. From February to April and again in September, no reactors were operating.

A marked reduction from 1969 occurred in releases of radioiodine from the chemical processing facilities. Effects of a reported atmospheric nuclear weapons test were detected temporarily in air and milk in December.

In late December 1969, two ducks collected during routine surveillance from the K reactor area trench were found to contain greater amounts of radioactivity, primarily phosphorus–32, than birds taken from the river. The trench received single-pass reactor coolant, and the ducks had apparently consumed algae from this site. Initial followup in January 1970, involved collection of waterfowl from all open ponds and trenches at the Hanford site. One duck was found at the K trench and one more with unusually high phosphorus–32 concentrations was found residing on the N reactor trench. Corrective action was taken to prevent further access by gamebirds. As in past years, none of the many gamebirds collected along the river and close to public hunting areas showed any similar concentrations of radionuclides.

Radioactivity in the Columbia River

Nuclides present in reactor effluent

Cooling of the Hanford production reactors (with the exception of N reactor) is accomplished by a single pass of treated Columbia River water. The N reactor uses recirculating demineralized water as a primary coolant. Some cooling water containing radioactive material is discharged to a ground disposal site with overflow to the N trench; liquid wastes are collected and transported to the chemical processing areas for processing and disposal. Most of the radionuclides discharged to the ground decay before reaching the river via passage through the soil. Others are absorbed or filtered by soil particles and retained. Although some of these radionuclides eventually enter the river, the total quantity of radioactivity entering the Columbia River from N reactor is a negligibly small fraction of that released from the single-pass reactors, and has generally not been detectable in the river at the downstream plant boundary.

At the older single-pass production reactors, some elements present in the cooling water are activated while passing through the reactors. Other elements adhere to films formed on surfaces of fuel elements and process tubes, are activated, and are eventually discharged with the cooling water to the river. Table 1 shows the relative abundance of the radionuclides found in the cooling water of the older single-pass production reactors, 4 hours after leaving the reactor.

Many of the radionuclides formed in reactor cooling water are short-lived and disappear quickly due to radioactive decay. In addition, sedimentation and uptake by aquatic organisms removes some fraction of most radionuclides from the river water. Small amounts of fission products are released to the river from the fissioning of natural uranium present in the water used for cooling, from occasional element cladding failures, and from weapons test fallout. Some radionuclides probably also entered

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Table 1. Relative abundance of reactor effluent radionuclides[a]

Percent of abundance					
Major (90 percent)	Minor (9 percent)	Trace (1 percent)			
^{24}Na	^{32}P	^{3}H	^{90}Sr	^{132}I	[b] ^{147}Pm
^{31}Si	^{46}Sc	^{14}C	^{91}Sr	^{135}I	[b] ^{149}Pm
^{51}Cr	^{69m}Zn	^{35}S	[b] ^{90}Y	^{136}Cs	[b] ^{151}Pm
^{56}Mn	^{72}Ga	^{45}Ca	[b] ^{91}Y	^{137}Cs	[b] ^{152}Eu
^{64}Cu	^{76}As	^{54}Mn	[b] ^{93}Y	^{140}Ba	[b] ^{156}Eu
	^{92}Sr	^{59}Fe	^{95}Nb	[b] ^{141}Ce	[b] ^{153}Gd
	^{122}Sb	^{60}Co	^{99}Mo	[b] ^{143}Ce	[b] ^{159}Gd
	^{133}I	^{65}Ni	^{103}Ru	[b] ^{144}Ce	[b] ^{160}Tb
	[b] ^{140}La	^{65}Zn	^{106}Ru	[b] ^{143}Pr	[b] ^{161}Tb
	[b] ^{152m}Eu	^{87m}Sr	^{124}Sb	[b] ^{145}Pr	[b] ^{166}Ho
	[b] ^{153}Sm	^{89}Sr	^{131}I	[b] ^{147}Nd	[b] ^{169}Er
	[b] ^{165}Dy				[b] ^{171}Er
	^{239}Np				

[a] Trace nuclide composition based on analyses made in 1964 and 1968.

[b] These radionuclides as a group are denoted hereafter as RE+Y (rare earths+yttrium).

the river from ground waste disposal sites, but their contribution to the total radioactivity in the river in 1970 was not detectable.

River flow rates

Seasonal fluctuations in flow rate of the Columbia River affect concentrations of radionuclides released to the river by varying the quantity of water available for dilution. In addition, the scouring of sediments deposited in reservoirs behind each Columbia River dam causes seasonal fluctuations in transport rates of those longer-lived nuclides accumulated in the sediments. The fluctuating flow rate also affects the time required for a specific volume of water to move from one location to another, which in turn affects the time available for decay of the shorter-lived nuclides before exposure to the public.

The weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams are determined from daily average flow rates published by the U.S. Geological Survey (*4*). For 1970, the average river flow rate at Priest Rapids was 2 790 m^3/s (96 400 ft^3/s) which was less than the 1948–1962 annual average of 3 770 m^3/s (133 000 ft^3/s).

River concentrations

During 1970, samples of river water were collected at Vernita upstream from the production reactors and below the reactors at the Richland water plant intake, and at Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents evaluation of the concentrations of radionuclides with very short half-lives; these were measured in monthly "grab" samples (*2*).

Table 2 shows the annual average radionuclide concentrations of selected radionuclides in river water at Richland and at Bonneville Dam for 1966–1970. The data for 1966 reflect the effects of complete reactor shutdown during July and August. Comparison of 1970 with 1969 concentrations indicates a major reduction for all radionuclides released to the river.

Table 3 shows concentrations for a larger list of nuclides at Richland and Vernita for 1970 only. Activation product nuclides and neptunium–239 are attributed to Hanford reactor operations. Strontium–90, plutonium–239, and total alpha-emitter concentrations are near or below analytical limits, and do not indicate a significant contribution from Hanford by com-

Table 2. Annual average concentrations of selected radionuclides in the Columbia River, 1966–1970

Radionuclide	Concentration (pCi/liter)									
	1966		1967		1968		1969		1970	
	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam
Phosphorus-32	140	23	190	25	92	15	73	14	28	5
Scandium-46	30	NA	60	18	100	20	72	NA	43	NA
Chromium-51	3 600	1 300	3 200	1 400	1 500	530	720	240	300	100
Zinc-65	200	43	220	62	86	<30	72	25	84	10
Iodine-131	18	3	8	3	7.4	<3.2	4.0	NA	<2	NA

NA, no analysis.

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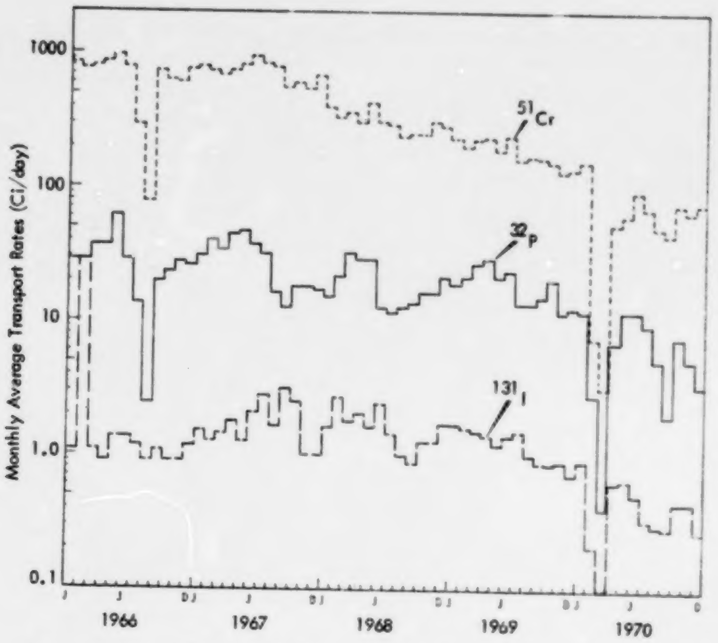

Figure 2. Phosphorous–32, chromium–51, and iodine–131 transport rates in the Columbia River at Richland

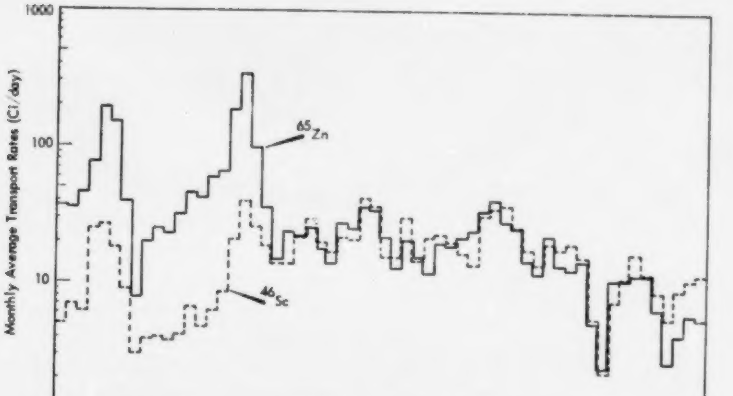

Figure 3. Scandium–46 and zinc–65 transport rates in the Columbia River at Richland

Table 3. Concentrations of radionuclides in the Columbia River at Richland and Vernita, 1970

Radionuclides	Analytical limit (pCi/liter)	Concentration guide (pCi/liter)	Concentration (pCi/liter)									
			Vernita					Richland				
			Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Alpha	0.5	[a] 30	12	0.97	(c)	0.59	2.0	12	1.2	(c)	0.60	2.0
Rare earth + yttrium[b]	5	[a] 40 000						5	670	180	340	.9
Hydrogen-3	1 000	3 000 000	12	2 600	(c)	840	.03	12	2 700	(c)	1 100	.04
Sodium-24	35	30 000						23	2 300	60	900	3.0
Phosphorus-32	6	20 000						44	93	9.1	28	.1
Scandium-46	20	40 000						51	120	(c)	43	.1
Chromium-51	70	2 000 000						51	1 200	(c)	300	.02
Manganese-56	50	100 000						5	230	63	100	.1
Copper-64	20	200 000						5	1 500	460	800	.4
Zinc-65	20	100 000						51	99	(c)	34	.03
Arsenic-76	5	20 000						5	180	48	130	.7
Strontium-90	.5	300	12	.61	(c)	.44	.1	12	.7	(c)	(c)	<.2
Antimony-122	5	30 000						5	460	42	120	.4
Iodine-131	2	300						51	5.4	(c)	(c)	<.6
Neptunium-239	10	100 000						5	1 400	320	570	.6
Plutonium-239	.025	5 000	2	(c)	(c)	(c)	.0005	2	(c)	(c)	(c)	<.000

[a] Calculated from isotopic mixture.
[b] Rare earths plus yttrium separation.
[c] Less than the analytical limit.

parison with upstream analyses at Vernita. The small increase in measured tritium concentrations between Vernita and Richland is probably due to releases from the operating reactors. The average concentration of any nuclide in the river at Richland during 1970 did not exceed 3 percent of the AEC standards.

Bonneville Dam, approximately 490 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 4).

Table 4. Annual average transport rates of selected radionuclides past Bonneville Dam, 1966–1970

Radionuclides	Transport rate (Ci/day)				
	1966	1967	1968	1969	1970
Phosphorus-32	9	12	6.2	7.1	2.3
Scandium-46	NA	10	7.5	NA	NA
Chromium-51	430	610	200	100	40
Zinc-65	21	40	<13	<15	4.7

NA, indicates no routine analysis was made.

Transport rates

Figures 2 and 3 show the river transport rates of several radionuclides past Richland for 1966 through 1970. The transport rates at Richland in 1970 for the five radionuclides shown were significantly lower than the 1969 values. Table 4 shows the annual average transport rates of selected radionuclides past Bonneville Dam.

Trend indicator—whitefish

The Columbia River is popular for sports fishing both above and below the Hanford reservation. Fish feeding downstream from the reactors contain some radionuclides originating from reactor effluent, acquired for the most part through food chains. Phosphorus-32 is the most significant of these nuclides with regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media, and the ultimate uptake of radionuclides at each trophic level depends on complex environmental interrelationships.

Whitefish are the sports fish that usually contain the greatest concentration of radioactive materials. Furthermore, they can be caught during winter months when other sports fish are difficult to sample. Therefore, phosphorus-32 data accumulated from whitefish sampling near the plant boundary are useful as a long-term trend indicator of concentrations in biological media, even though whitefish are not the most significant source of radionuclides for the local fish-consuming population.

Concentrations of phosphorus-32 in whitefish during 1970 tend to follow the same seasonal trends observed in past years. As expected from river concentrations, the average concentration of phosphorus-32 in whitefish sampled downstream from the reactors during 1970 decreased to 17 pCi/g from 34 pCi/g during 1969 (*1*).

Radioactivity in groundwater

Radioactivity in the groundwater beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities, dependent upon their radionuclide burden and chemical content. High-level wastes[4] are stored in underground concrete tanks lined with steel. Intermediate-levels wastes[5] are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the waste disposal and high-level waste storage have soil with good ion exchange capacity and

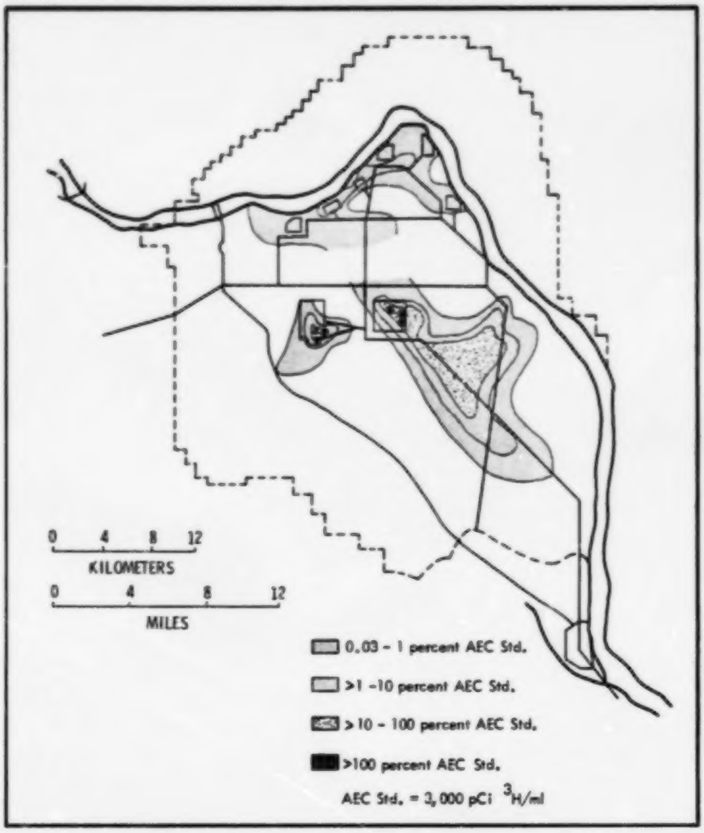
0 4 8 12
KILOMETERS
0 4 8 12
MILES
▨ 0.03 - 1 percent AEC Std.
▨ >1 -10 percent AEC Std.
▨ >10 - 100 percent AEC Std.
■ >100 percent AEC Std.
AEC Std. = 3,000 pCi ^{3}H/ml

Figure 4. Tritium concentrations in groundwater, Hanford, July–December 1970

groundwater depths of 50 to 100 m. Low-level wastes[a] are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

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[4] High-level: >100 mCi/liter.
[5] Intermediate-level: 50 nCi/liter to 100 mCi/liter.

One important objective in the management of wastes placed in the ground is to prevent radionuclides from reaching the groundwater in quantities that could cause significant human radiation exposure should they ultimately migrate to the Columbia River. An extensive groundwater surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford project, including sites within and near ground disposal and tank storage areas, to monitor the movement of radionuclides in the groundwater.

The radioactivity reaching the groundwater from the chemical separations areas is primarily tritium and ruthenium–106; cobalt–60, and technetium–99 have also been found but at much lower concentrations. The more radiotoxic nuclides, such as strontium–90, have not been detected in groundwater except in the immediate vicinity of a few specific disposal sites.

Figures 4 and 5 show the probable extent of detectable tritium and ruthenium–106 in groundwater beneath the Hanford project as of December 31, 1970 (5). The outer boundary of the contamination contours, i.e., 0.03 percent of the AEC standard for tritium and 2 percent of the AEC standard for ruthenium–106, repre-

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[a] Low-level: <50 nCi/liter.

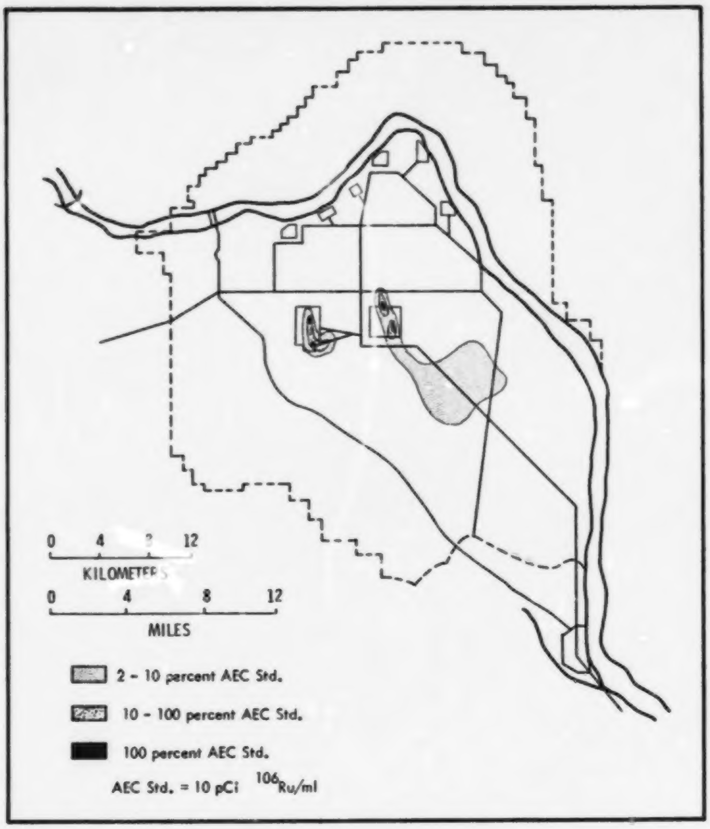
0 4 8 12
KILOMETERS
0 4 8 12
MILES
▨ 2 - 10 percent AEC Std.
▨ 10 - 100 percent AEC Std.
■ 100 percent AEC Std.
AEC Std. = 10 pCi ^{106}Ru/ml

Figure 5. Ruthenium–106 concentrations in ground water, Hanford, July–December 1970

sent the detection levels routinely achievable for those radionuclides.

It is possible that some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too small to be routinely measurable in the groundwater near the river or in the river itself, and any radiation dose from them is negligible.

Tritium in the groundwater near the river in the vicinity of the N reactor area may have contributed to the small increase in tritium concentration observed in the river between Vernita and Richland in 1970 (table 3), but any resulting dose from offsite drinking water would still be negligible.

A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to those confined aquifers, are routinely sampled for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from non-Hanford sources in recent precipitation can also occur. Samples from all five offsite wells during 1970 were at or less than the analytical limit for tritium and nitrate ion.

Radioactivity in drinking water

The city of Richland, about 75 km (47 miles) downstream from the Hanford reactors, is the first community below the project that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the river as a water source. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Ranney well collectors (infiltration pipes) laid in the riverbank.

During 1970, cumulative and periodic grab water samples were collected at both the Richland and Pasco water plants and analyzed for selected individual radionuclides and gross beta activity (table 5). The Pasco sampling was discontinued at midyear since the calculated dose-rate from drinking water was uniformly less than at Richland and was becoming less and less significant. At each plant, water was sampled after treatment and just prior to entering the city distribution system.

The concentrations of short-lived radionuclides in the water at the time it is consumed were less than shown in table 5 because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending

Table 5. Concentrations of several radionuclides in Richland drinking water,[a] 1970

Radionuclide	Number of samples	Concentration (pCi/liter)			Percent of AEC standard
		Analytical limit	Richland	AEC standard	
Total beta (counts per min/ml)	95	0.2	1.0	[b] 2 000 000	<0.1
Sodium-24	9	35	640	30 000	2.1
Phosphorus-32[c]	52	6	16	20 000	<.1
Chromium-51	4	70	410	2 000 000	<.1
Zinc-65	52	20	20	100 000	<.1
Arsenic-76	4	5	41	20 000	.2
Antimony-122	4	5	42	30 000	.1
Iodine-131[c]	52	2	2.0	300	.7
Iodine-133	9	10	13	1 000	1.3
Neptunium-239	9	10	220	100 000	.2
Rare earths + yttrium[d]	4	5	26	[b] 40 000	<.1

[a] Measured at the water plants.
[b] Calculated from isotopic ratios.
[c] Results based on cumulative samples.
[d] Rare earths plus yttrium fraction.

upon the location of the customers on the distribution system and the water demand.

The nuclide showing the largest average percentage of the AEC standard in Richland drinking water during 1970 was sodium–24, about 2 percent.

Annual average concentrations of radionuclides measured at the Richland water plant were used to calculate the doses from drinking water for comparison with past years. The correlation between the GI tract dose rate at the water plant (established by direct measurement of individual radionuclide concentrations) and the gross beta activity was determined monthly. This correlation, used in conjunction with thrice-weekly measurements of gross beta activity at the water plant, provided the basis for estimation of the GI tract dose. The estimated annual GI tract dose to Richland residents from the measured radionuclides in drinking water continued to decrease in 1970 (10 mrem) from 1969 (17 mrem).

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1961 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, perch, and bass) taken from the Columbia River. Additional dietary data collected during 1966 and 1967 from household questionnaires and interview surveys also showed individual consumption estimates as high as 200 meals of fish per year (*6*). The primary fishing locations for the catch of these fish were Burbank, Hover-Finley, and Island View. The average percentage of the maximum annual consumption by species was 73 percent crappie, 16 percent bass, and 11 percent perch. Based on data collected during 1970, the average concentration of phosphorus–32 in such a mixture of panfish was about 5 pCi/g, and that of zinc–65 was 2 pCi/g. Gamma scans of samples showed no other radionuclides present on the average above the analytical level.

From this species distribution and radiochemical analyses of the specimens collected, the "maximum individual's" estimated intakes during 1970 were 0.20 μCi of phosphorus–32 and 0.08 μCi of zinc–65 (*1*) or less than one-half the corresponding intakes during 1969. The calculated dose to the bone of the "maximum individual" for 1970 from this source was 38 mrem or about 2.5 percent of the standard of 1 500 mrem per year.

The average consumption of Columbia River fish by Richland residents was estimated from diet questionnaires completed by Hanford plant employees (*3*). Assuming the same mixture of species as for the maximum individual, the average Richland resident's intake during 1970 was estimated to be 0.002 μCi phosphorus–32 and 0.001 μCi zinc–65. These intakes correspond to a bone dose of about 0.5 mrem or about 0.1 percent of the standard of 500 mrem per year for the population average.

Radioactivity in shellfish

Zinc–65 and phosphorus–32 are the only radionuclides from Hanford reactor effluents that have been found in sufficient abundance in seafoods collected beyond the mouth of the Columbia River to be of significance to human radiation exposure. Oysters have been found to contain higher concentrations of zinc–65 than other common seafoods (*3*). Oyster samples were obtained during 1970 from commercial sources at Willapa Bay, Wash. This area is a major regional commercial source of oysters and, because of prevailing ocean currents, a likely location for maximum concentrations of Hanford nuclides in shellfish.

Monthly average concentrations of phosphorus–32 and zinc–65 were periodically measured in oysters grown commercially in the Willapa Bay area. A normal seasonal minimum for phosphorus–32 occurs in the late summer. The zinc–65 data for 1970 show a decrease through the year approximating the radioactive half-life. The annual average concentrations for 1970 were 0.13 pCi/g of zinc–65 and 0.06 pCi/g of phosphorus–32.

Fresh shellfish are not an important item in the average tri-cities diet, but residents of some coastal areas may consume more than the reference value of 50 g/day (*7*). For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin. Consumption of oysters containing the 1970 average concentrations of phosphorus–32 and zinc–65 at the rate of 50 g/day would result in annual doses of about 2.5 mrem to the GI tract, 1.6 mrem to the whole body, and 2.9 mrem to the bone of a standard man (*8*). This calculated whole body dose is about 0.3 percent of the appropriate dose standard of 500 mrem per year.

Radionuclides in game birds

Waterfowl and other gamebirds utilizing the river downstream from the reactors or open low-level waste disposal sites within the plant boundaries may ingest phosphorus–32, zinc–65, and other radionuclides with their intake of insects, algae, vegetation, and water containing these radionuclides. Although the spring and fall migrations bring a temporary influx of great numbers (up to 200 000 birds), some waterfowl remain in this general area throughout the year. The river also provides cover, food, and water for a local population of pheasant, quail, and other upland gamebirds. The concentrations of radionuclides in the flesh of gamebirds at the time of consumption are dependent upon the bird species, the geographical locations from which the birds are taken, their residence time in the vicinity, their current feeding habits, and the elapsed time between killing and consumption of the birds.

Table 6 shows radionuclide concentrations in the muscle (the edible portion) of gamebirds collected along the river within the Hanford project for the environmental monitoring program during hunting seasons in 1970. The maximum concentration in such birds during 1970 was 170 pCi ^{32}P/g, for comparison, the maximum observed in 1969 was 510 pCi ^{32}P/g for birds collected in the same area.

Data from a dietary survey of Hanford employees (*3*), from a special survey of local hunters (*6*), and from the radionuclide concentration data for the various species have been combined to estimate the species mix and the radionuclide content of an average local gamebird meal. About 30 percent of the gamebird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Past analyses have shown that pheasants collected beyond this distance contain little, if any, radioactivity of Hanford origin. About 44 percent of all birds eaten were reported to have been placed in frozen storage, which would permit appreciable decay of any phosphorus–32 before consumption.

The maximum total gamebird consumption by adults reported to date is 100 meals per year, or an estimated 32 kg/yr. Consumption of this weight of the "average gamebird meal" (table 7) would result in intakes of 0.022 μCi of phosphorus–32 and 0.014 μCi of zinc–65, implying a dose of 4.2 mrem to the skeleton, or less than 0.4 percent of the standard for individual members of the population. Consumption of 1.24 kg/yr, the estimated annual intake for the "average" Richland resident, would result in a total dose of about 0.2 mrem to the skeleton, less than 0.1 percent of the appropriate standard of 500 mrem/yr.

Table 6. Radionuclide concentrations in game birds, 1970

Species	Number of samples	Concentration (pCi/g)											
		Phosphorus-32			Cobalt-60			Zinc-65			Cesium-137		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Geese [a] (river)	18	49	(c)	13	150	(c)	8.3	9.0	0.23	3.2	0.31	(c)	0.14
Duck [a] (river)	79	170	(c)	7.1	.16	(c)	(c)	9.2	(c)	1.6	.25	(c)	.04
Pheasant [b]	34	26	(c)	3.1	.41	(c)	(c)	8.4	(c)	2.1	.31	(c)	.09
Quail [b]	23	17	(c)	2.0	(c)	(c)	(c)	4.0	(c)	1.0	2.4	(c)	.18
Analytical limit			1.0			0.15			0.2			0.1	

[a] Collected on the Columbia River within the Hanford boundary.
[b] Collected within 5 km (3 miles) of the Columbia River and within the Hanford boundary.
[c] Less than the analytical detection limit.

Table 7. Contribution[a] of each species to 100 grams of an average game bird meal, 1970

Species	Weight (grams)	Radionuclide content (pCi)	
		Phosphorus–32	Zinc–65
Duck	23	46	10
Goose	6	16	10
Quail	12	5	2
Pheasant	47	26	36
Grouse	13	2	1
Total	100	95	59

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no phosphorus–32 or zinc–65 in other birds. Also weighted for frozen storage by assuming complete decay of phosphorus–32 but no significant decay of zinc–65 during frozen storage of 44 percent of the birds.

The dose calculations shown above do not include four ducks collected at the K and N reactor area trenches between the last week in December 1969 and the first week in March 1970. Muscle tissue from these four birds, of 15 collected at these locations during this period, showed concentrations from 0.03 to 0.14 μCi ^{32}P/g, compared to a maximum in birds collected along the river of 0.000 17 μCi ^{32}P/g. Analysis of gizzard contents indicated some feeding on filamentous algae present in the water in the trenches. Steps were taken to prevent further access by waterfowl, including partial backfilling and screening the remaining open areas of the trenches.

Immediate consumption of 230 g (one-half pound—a normal meal) of flesh with the highest concentration, with consequent ingestion of about 30 μCi of phosphorus–32, would have resulted in a calculated skeletal-bone dose to an adult of about 6 rem, four times the applicable annual dose standard. The associated whole body dose, including a contribution from zinc–65, would have been about 250 mrem, or about 15 percent of the applicable annual dose standard.

Even were such a bird to be shot by a hunter, delays between the time a bird left a trench and the time of shooting, and as a result of the frequent practice of freezing gamebirds for later consumption would have permitted significant radioactive decay. This would further reduce the probability of consuming flesh containing the higher concentrations of phosphorus–32. For the bird with the maximum concentration that has been considered here, any delays in consumption of more than 4 weeks would have reduced the skeletal bone dose to less than 1 500 mrem (the annual standard).

The consumption of such a bird by any member of the public, however, is considered highly improbable in view of the facts that: (a) very few birds (out of some 200 000 in the area at that time) would have been likely to spend sufficient time on the trenches near the reactor areas to accumulate such large amounts of radioactive materials, and (b) concentrations of this magnitude have never been found in hundreds of birds sampled along the river for over 20 years. In our judgment, ducks collected on swamps, trenches, or ponds are not representative of those available to the general population, and dose estimates derived therefrom are not pertinent for inclusion in comparisons with the established dose standards.

Radioactivity in milk and produce

Irrigation with river water containing radionuclides can contribute radioactivity to local milk and locally-grown farm produce, as can deposition of airborne materials from weapons test fallout and from Hanford sources. Chemical separations facilities would generally be the principal local source of airborne radionuclides other than fallout, although unusual radioactivity releases could occur from ventilation stacks of reactor or laboratory facilities.

The farming area closest to the separations facilities is at Ringold about 21 km (13 miles) away. Much of the land east and south of the project boundary is under cultivation and may be in the path of airborne releases. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district west of Pasco. These are 40 and 65 km (25 and 40 miles), respectively, downstream from the operating reactors.

The milk surveillance program maintained during 1970 included samples from local farms and dairies and from commercial supplies avail-

Table 8. Radionuclide concentrations in local milk, 1970

Location	Radionuclide concentration[a] (pCi/liter)																	
	Iodine–131				Phosphorus–32					Zinc–65			Strontium–90				Cesium–137		
	Number of samples	Maximum	Average	Percent of AEC standard	Number of samples	Maximum	Average	Percent of AEC standard	Number of samples	Maximum	Average	Percent of AEC standard	Maximum	Minimum	Average	Percent of AEC standard	Maximum	Average	Percent of AEC standard
Riverview	52	3.6	0.84	0.3	52	1 200	210	1	52	300	120	0.1	9.1	2.9	5.0	1.6	49	7.8	<0.1
Benton City & West Richland composite	62	10	1.3	.4					39	60	28	<.1					25	5.8	<.1
Benton City	11	3.2	1.2	.4					11	82	50	<.1	4.6	3.5	4.1	1.3	27	18	<.1
Columbia Basin composite No. 2	27	2.5	1.1	.4	27	74	23	.1	27	64	32	<.1	4.6	ND	2.2	.7	31	7.2	<.1
Columbia Basin composite No. 3	88	4.4	.92	.3					38	83	36	<.1					44	9.7	<.1
Commercial	56	21	.83	.3					24	77	35	<.1	9.5	ND	3.6	1.2	34	14	<.1
AEC standard	300				20 000				100 000				300				20 000		
Analytical limit	2				6				50				2				30		

[a] Where no minimum value is shown, all minimum values were less than the analytical limit. ND, less than the analytical limit.

able to people in the tri-cities. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus–32 and zinc–65 as well as fission products from fallout and possibly Hanford sources. Commercial milk distributed in the tri-cities normally does not contain detectable phosphorus–32 and zinc–65, because only a small fraction of the milk is produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

Table 8 gives concentrations for an expanded list of radionuclides in milk and table 9 gives produce for 1970. During 1970, the annual average concentrations of phosphorus–32 and zinc–65 for the Riverview farm were 210 and 120 pCi/liter compared to 1969 averages of 160 and 110 pCi/liter, respectively, for the same farm. Seasonal fluctuations in concentrations of both phosphorus–32 and zinc–65, caused primarily by irrigation and feeding practices, followed expected trends. Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from phosphorus–32 and zinc–65 of about 15 mrem to the bone (1 percent of the applicable dose standard).

Iodine–131 concentrations in both farm milk and commercial milk during 1970, were consistently less than the analytical limit of 2 pCi/liter. The maximum iodine–131 concentration of 21 pCi/liter for the period was measured in a sample of commercial milk collected in December and was attributed to atmospheric weapons testing.

The concentrations of other fallout nuclides, strontium–90 and cesium–137, in the local environs are usually below the national average because of the low rainfall. Concentrations of strontium–90 in locally produced farm and commercial milk (table 8) were similar in 1970 to those in commercial milk produced in other areas remote from the Hanford plant.

Fresh produce, meat, and eggs from local sources were sampled periodically for radioanalysis during the 1970 growing season and compared with samples from commercial sources. Results of these measurements were lower than those of previous years as expected, and indicated that only small quantities of

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Table 9. Radionuclide concentrations in local foods, 1970

Foodstuffs	Radionuclide concentration [a] (pCi/g)											
	Phosphorus-32			Number of samples	Zinc-65			Strontium-89		Strontium-90		
	Number of samples	Maximum	Average		Maximum	Minimum	Average	Maximum	Average	Maximum	Minimum	Average
Farm meat	5	2.5	1.6	8	4.6	.5	2.4	-------	-------			
Commercial meat	13	2.0	.31	27	.12	ND	.04	-------	-------	0.013	ND	0.005
Commercial poultry	-------	-------	-------	1	ND	ND	ND					
Farm poultry	7	.22	.08	7	1.0	ND	.55	ND	ND	ND	ND	ND
Commercial eggs	-------	-------	-------	4	.042	ND	ND					
Farm eggs	16	5.6	1.2	16	2.5	ND	.54	0.011	0.006	.002	ND	.0015
Farm fruit	9	.15	.036	11	.14	ND	.078	-------	-------	.025	ND	.008
Farm leafy vegetables	7	.49	.28	9	.60	ND	.28	.00[illegible]	.00[illegible]	.06	0.01	.039
Farm other vegetables	9	.18	.06	11	.21	ND	.09	-------	-------	.68	.005	.13
Commercial leafy vegetables	6	.49	.12	6	.12	ND	ND	.033	.012	.031	ND	.017
Commercial fruit and vegetable composite	4	.07	ND	4	.12	.06	.09	-------	-------	.008	.006	.006
Analytical limit	1.0			0.05				0.02		0.002		

	Number of samples	Zirconium-niobium-95		Ruthenium-106		Iodine-131		Cesium-137		Cerium-praseodymium-144	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Farm meat	8	0.04	0.01	ND	ND	ND	ND	0.04	0.02	ND	ND
Commercial meat	27	ND	ND	ND	ND	ND	ND	.066	.027	ND	ND
Commercial poultry	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Farm poultry	7	ND	ND	ND	ND	ND	ND	.038	.020	ND	ND
Commercial eggs	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Farm eggs	16	ND	ND	ND	ND	ND	ND	.025	ND	ND	ND
Farm fruit	11	.025	ND	ND	ND	ND	ND	.036	.013	ND	ND
Farm leafy vegetables	9	.71	.16	0.89	0.17	0.41	0.04	.170	.056	1.3	0.41
Farm other vegetables	11	ND	ND	ND	ND	ND	ND	.062	.011	ND	ND
Commercial leafy vegetables	6	.26	.06	ND	ND	ND	ND	ND	ND	ND	ND
Commercial fruit and vegetable composite	4	ND	ND	ND	ND	ND	ND	.038	ND	ND	ND
Analytical limit		0.03		0.6		0.05		0.02		1.0	

[a] Where no minimum value is shown, all minimum values were less than the analytical limit.
ND, less than the analytical limit.

radionuclides from Hanford were present in locally-grown produce. However, a resident of a local farm, consuming eggs and one-half pound of beef per day raised on pasture irrigated with water taken from the river downstream from the reactors, could have received a bone dose up to 30 mrem for the year, 2 percent of the applicable standard.

Radioactivity in the atmosphere

Gaseous effluents from the Hanford chemical separations facilities are released to the atmosphere through tall stacks after passage through high-efficiency filters. Laboratory stacks, reactor-building stacks, and stacks from waste storage facilities may also release small amounts of particulate radioactive materials. The reactors release some noble gases, mostly argon–41, to the atmosphere under normal operating conditions.

During 1970, measurements of airborne iodine–131, gross beta, and total alpha were routinely made at 23 locations offsite and around the Hanford reservation boundary; locations are shown in figure 6. Airborne data concentrations followed the annual cycle observed in previous years and showed about the same maximum and minimum values as for 1969.

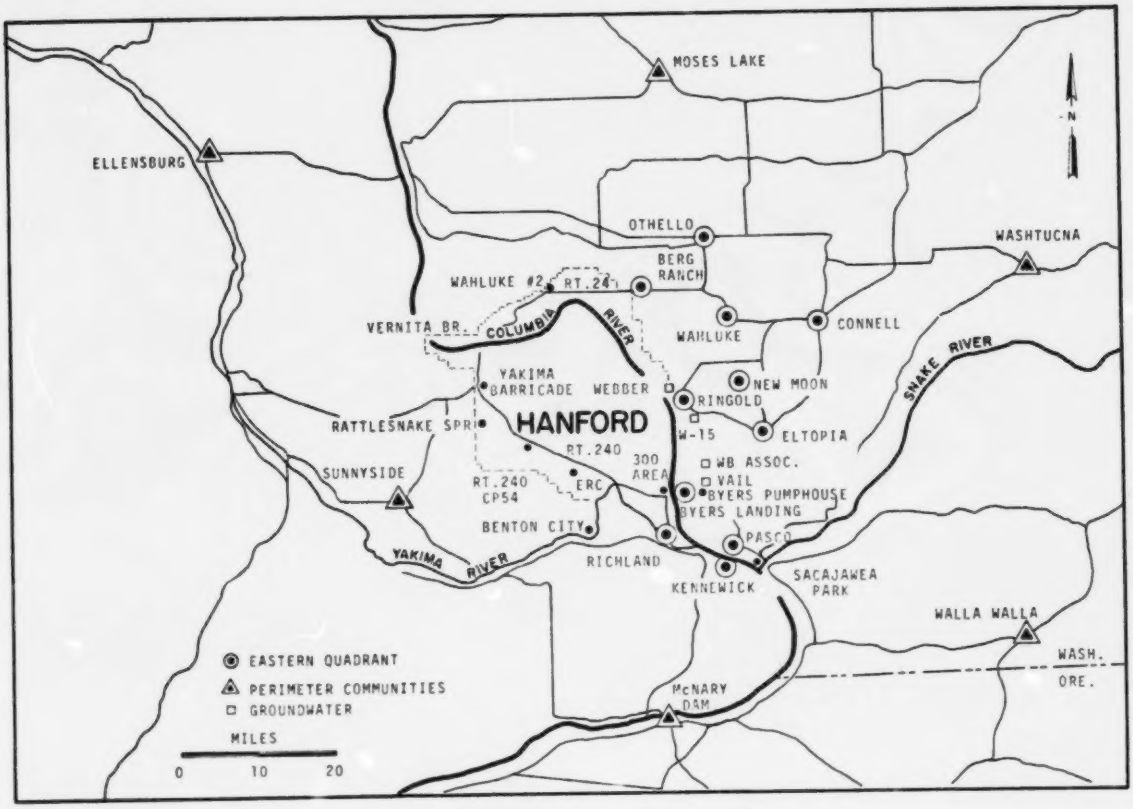
MOSES LAKE
N
ELLENSBURG
OTHELLO
WASHTUCNA
BERG RANCH
WAHLUKE #2
RT.24
VERNITA BR.
COLUMBIA
RIVER
WAHLUKE
CONNELL
SNAKE RIVER
YAKIMA BARRICADE
WEBBER
NEW MOON
RINGOLD
HANFORD
RATTLESNAKE SPR.
W-15
ELTOPIA
RT.240
300 AREA
WB ASSOC.
VAIL
SUNNYSIDE
RT.240 CP54
ERC
BYERS PUMPHOUSE
BYERS LANDING
BENTON CITY
PASCO
YAKIMA RIVER
RICHLAND
KENNEWICK
SACAJAWEA PARK
WALLA WALLA
WASH.
ORE.
McNARY DAM
◉ EASTERN QUADRANT
△ PERIMETER COMMUNITIES
□ GROUNDWATER
MILES
0
10
20

Figure 6. Offsite air sampling locations

Tables 10 and 11 present a more detailed review of the 1970 airborne radioactivity data. Analyses for strontium-90 and total plutonium alpha were made quarterly on composited filters from several locations. The results are given in table 11, with average total alpha and gross beta concentrations for comparison. Locations within each group are given in table 10. The data show that plutonium alpha accounted for less than 1 percent of the total alpha activity and strontium-90 for about 2 percent of the gross beta activity. The radioactivity measured is believed to be essentially all of natural origin or from regional fallout.

Insufficient isotopic data were available to determine appropriate AEC standards for gross alpha and beta. However, the average airborne total alpha and gross beta concentrations at the Hanford boundary locations were the same as the average at more distant sampling locations, indicating that Hanford operations did not contribute measurably to offsite airborne radioactivity.

External radiation

Land measurements

Prior to June 1970, ionization chambers (100 ml nominal volume) were used at a limited number of locations for basic gamma radiation measurements. Pocket ionization chambers (gamma pencils) were also used at all air sampler locations in order to distinguish major changes in gamma radiation levels. Table 12 shows measurements of an onsite and offsite location over a 5-year period. The upward trend is believed to be due to increased deposition

Table 10. Radioactivity in air, 1970

Location	Total alpha (pCi/m³)				Total beta (pCi/m³)			Iodine-131 (pCi/m³)							
								January-June 1970				July-December 1970			
	Number of samples	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Percent of AEC standard	Maximum	Minimum	Average	Percent of AEC standard
Southeast quadrant:															
Berg Ranch	39	0.042	0.001	0.011	0.99	0.05	0.27	0.029	ND	0.011	0.01	0.39	ND	0.12	0.1
Wahluke Watermaster	13	NA			0.84	.10	[a].31					.28	ND	.096	.1
Wahluke Slope #2	21	NA			1.1	.03	.41	(a)	ND	.010	.01				
New Moon	39	.032	.003	[a].010	.88	.03	.26	.051	ND	.012	.01	.25	ND	.048	.05
Eltopia	39	NA			1.0	.03	.34								
Ringold	39	.027	.001	.011	1.3	.06	.31	.45	ND	.016	.02	.26	ND	.10	.1
Byers Landing	39	.038	.001	.012	1.4	.02	.35	.033	ND	.008	.01	.21	ND	.059	.06
Richland	39	.044	.001	.013	1.3	.06	.37	.026	ND	.007	.01	.18	ND	.068	.07
Pasco	39	.045	.005	[a].016	1.3	.02	.37	.026	ND	.009	.01	.16	ND	.076	.08
Kennewick	12	.039	.002	.014	.50	.02	[a].23					.12	ND	.029	.03
Benton City	39	.046	.001	.012	.92	.04	.32	.028	ND	.009	.01	.12	ND	.043	.04
Southeast quadrant average				.012			.32			.010				.071	.07
Perimeter communities:															
Walla Walla	39	.078	.002	[a].018	1.5	.03	.33								
McNary Dam	39	NA			1.0	.06	.33								
Washtucna	37	NA			1.2	.02	.38								
Moses Lake	31	NA			1.0	.02	.31								
Ellensburg	26	NA			1.2	.04	.21								
Sunnyside	41	NA			1.0	.01	.33								
Othello	13	.033	.002	[a].014	.54	.02	[a].26								
Connell	11	NA			.57	.06	[a].24								
Perimeter average				.016			.30								
Analytical limit	0.001				0.02			0.02				0.02			
AEC standard								100				100			

[a] Six months of data only.
ND, less than the analytical limit.
NA, no analysis.

Table 11. Radioactivity in air, quarterly average, 1970

Location and date	Concentration (pCi/m³)					
	Average gross beta	Strontium-90	Percent of AEC standard	Average total alpha	Plutonium alpha	Percent of AEC standard
Southeast quadrant:						
Jan-Mar	0.15	NA		0.004	NA	
Apr-June	.48	NA		.017	NA	
July-Sept	.52	0.005	0.05	.021	0.000 04	0.2
Oct-Dec	.15	.0027	.03	.009	.000 03	.15
Annual or 6-month average	.32	.004	.04	.014	.000 035	.2
Perimeter communities:						
Jan-Mar	.14	NA		NA	NA	
Apr-June	.50	NA		NA	NA	
July-Sept	.44	.015	.15	.017	.000 03	.15
Oct-Dec	.15	.001	.01	.014	.000 04	.2
Annual or 6-month average	.31	.008	.08	.015	.000 035	.2
AEC standard	100	10		0.03	0.02	

NA, no analysis.

Table 12. Average external radiation exposure rates 1966–1970

Location	Exposure rate (mR/day)				
	1966	1967	1968	1969	1970
Hanford test location	0.35	0.35	0.36	0.37	0.39
Richland	.28	.26	.28	.30	.34

from weapons test fallout, as essentially all of the population exposure at Richland is from natural background and worldwide fallout from nuclear testing.

The chambers, however, have a limited response range (2 mR), and are prone to erroneous readings from mechanical shock, moisture, and dust. The best estimates of environmental gamma radiation dose based on chamber readings are, therefore, apt to be high. In June 1970, thermoluminescent dosimeters (TLD–200)[7] in an experimental shielded package, were installed at all air sampling locations to measure the gamma radiation exposure at 1 meter above ground level. Table 13 shows the average exposure rates for the same location groups used in table 10, the perimeter communities being the most distant locations. The difference of 0.01 mR/day between the two location groups is not statistically significant. The indicated annual exposure of about 60 mR/year implied by the data in table 13 is believed to be low, but the data are considered valid for comparative purposes.

Table 13. Average external radiation exposure rates TLD, July-December 1970

Location	Exposure rate (mR/day)		
	Maximum	Minimum	Average
Perimeter communities	0.32	0.10	0.16
Southeast quadrant	.24	.11	.17

Columbia River shoreline

Estimates of the external radiation dose received from recreational use of the Columbia River shoreline in the vicinity of the Hanford project have been based on routine measurements along the shoreline at Vernita (upstream from the reactor), at Richland, and at Sacajawea Park (where the Snake River enters the Columbia). The exposure rate measured at the shoreline may include components from radioactivity accumulated in sediment deposits and algae growth at the river's edge as well as from any radioactive material in the water. The average exposure rates at the three shoreline locations were measured with a 40-liter ionization chamber, 1 meter back from the water's edge and centered 1 meter above the ground; this approximates the dose rate to the gonads of a person standing on the riverbank. Average shoreline exposure rates (table 14) at these two locations were 0.43 mR/day at Richland and 0.53 mR/day at Sacajawea Park, or 160 and 190 mR/yr, respectively. The average exposure rate at Vernita, upstream of the Hanford plant, was 0.38 mR/day, indicating a small dose increment from Hanford. The maximum recreational user of the river is estimated from local fishermen interviews to spend not more than 500 hours per year along the river shoreline (*6*).

Table 14. Gamma exposure rates at the Columbia River shoreline, 1970

Location	Exposure rate			
	(mR/day)			(mR/year)
	Maximum	Minimum	Average	Average
Vernita	0.98	0.24	0.38	140
Richland	.86	.14	.43	160
Sacajawea Park	1.0	.31	.53	190

Immersion dose

The immersion dose received by tri-city swimmers is based on April through October exposure rates at Richland. Thermoluminescent dosimeters, positioned about 1 meter below the surface of the Columbia River, were substituted for pocket ionization chambers beginning in June 1970. Measured immersion exposure rates were due to gamma emitters in the river from all sources, including Hanford reactors. In the vicinity of Richland, the average measured immersion exposure rate for 1970 was 0.42 mR/day. For comparison, the immersion exposure rate measured upstream at Vernita was 0.16 mR/day.

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[7] Harshaw Chemical Company, CaF_2 (Dy).

Teenagers are the major recreational users of the Columbia River locally. A survey of 430 Richland teenagers in 1968 indicated an average exposure time of about 115 hours in or along the river for members of this group. About one-third of the time was probably immersion and about two-thirds was shoreline exposure (*10*). Using the annual average shoreline exposure rate and the April through October average immersion exposure rate at Richland, the average exposure to the teenage population was estimated to be about 2.1 mR during 1970.

The average whole body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers, but with the same proportion of immersion and shoreline exposure times. For the average exposure of the Richland population, an annual Columbia River (recreation) time of 32 hours was assumed (*10*). Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland, the whole body dose received by the "average" Richland resident during 1970 was estimated to be less than 0.6 mrem.

Surface measurements

Roads and land surfaces in the vicinity of Hanford were periodically surveyed for possible radionuclide deposition resulting from Hanford operations. Eleven small areas, called control plots, are located around the Hanford boundaries. These plots, measuring 3 m × 3 m (10 feet × 10 feet), were surveyed monthly or semimonthly with a GM survey meter for deposited radioactive material. No surface radioactivity of Hanford origin was detected on the control plots during 1970.

Public Highway 240, which traverses the Hanford reservation, was surveyed monthly with a bioplastic scintillation detector attached to the bumper of a truck positioned about 0.6 m (2 feet) above the edge of the road surface. This road monitor has been described in document BNWL–62 (*11*). During 1970, no radioactivity was detected by these surveys.

Aerial surveys can be used to detect contamination which is spread over a large area. Like road and control plot surveys, aerial surveys are only quantitative in nature, but through routine use of this technique, a capability for rapid assessment of an emergency situation is maintained. Aerial surveys at Hanford are conducted at an altitude of 150 m (500 feet) using a 3-inch by 5-inch thallium-activated sodium iodide scintillation crystal detector. Aerial survey flight patterns used during 1970 were:

1. near the Hanford project perimeter,
2. 15 to 40 miles beyond the project perimeter, and
3. following the Columbia River from the Vernita Bridge (upstream of the Hanford reactors) downstream to McNary Dam.

During 1970, no significant changes were seen in previously observed patterns.

Fallout from nuclear weapons tests

Measurements of fallout radiation, like measurements of natural background radiation, are all of interest for comparison with the radiation doses resulting from Hanford operations. Dose increments received by residents of the Hanford environs from the fallout nuclides tritium, strontium–90, and cesium–137 have been estimated routinely although they are not included in the assessment of dose attributable to Hanford operations. The concentrations of fallout nuclides in the local environs are below the national average because of the low rainfall.

Several positive analyses for iodine–131 concentrations in milk samples during 1970 were attributed to fallout from weapons testing. Estimates of fallout tritium intakes from drinking water were based on upstream concentrations measured in river water (table 3). Concentrations of strontium–90 and cesium–137 in locally produced farm and commercial milk (tables 8 and 9) were similar to those in commercial milk produced in areas remote from the Hanford plant (*12*), and worldwide fallout was assumed to be the sole source of strontium–90 and cesium–137 in milk.

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Assuming that 40 percent of an individual's total strontium–90 intake is obtained from milk (*13*), the intake of strontium–90 for 1970 was estimated to be 5.1 nCi for the "maximum" individual and 1.2 nCi for the "average" Richland resident. The total intake of cesium–137 during 1970 was about 22 nCi for the "maximum" individual and 5.2 nCi for the "average" Richland resident.

Table 15 shows a summary of the estimated annual dose commitments from fallout nuclides present in the Hanford environs in 1970. The estimated strontium–90 annual intake for the "maximum" individual and for the "average" adult Richland resident, evaluated in terms of the Federal Radiation Council guides (*16*), both correspond to 2 percent of the upper end of Range II (200 pCi/day for the average intake by a suitable sample of the exposed population and 600 pCi/day for individuals).

Table 15. Radiation dose commitments[a] from ingestion of individual fallout nuclides, 1970

Organ	Dose (mrem)			
	Tritium	Strontium–90	Cesium–137	Total
Maximum individual:				
Bone	NA	[b] 49	1.6	51
Whole body	<1	[b] 4.6	[c] <1	5
GI tract	NA	<1	<1	<1
Average adult Richland resident:				
Bone	NA	[b] 12	<1	12
Whole body	<1	[b] 1.1	[c] <1	1
GI tract	NA	<1	<1	<1

[a] Not included in dose summaries presented elsewhere.

[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods (*8, 14*). Only a few percent of the total dose commitment from strontium–90 intake is received during the first year for each of these organs.

[c] For the whole body dose commitment from ingestion of cesium–137 by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used (*15*).

NA, no analysis.

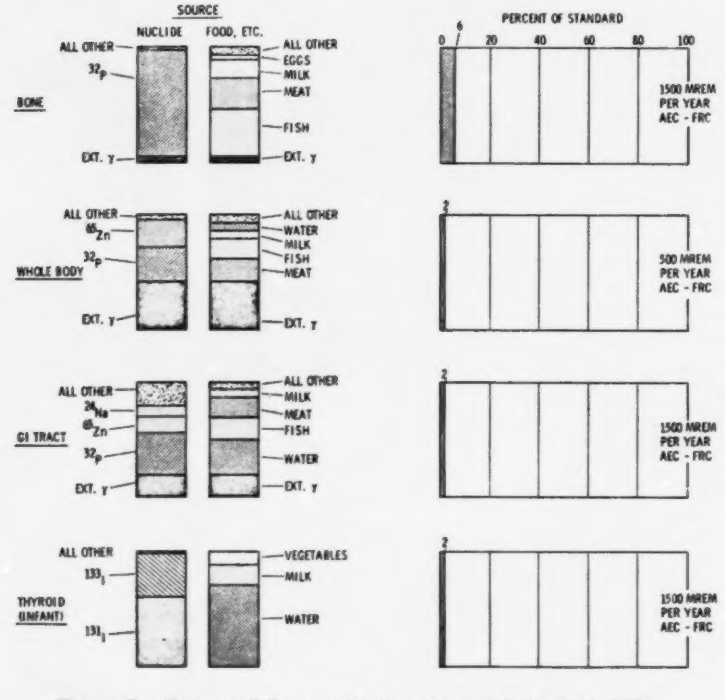

Figure 7. Estimated doses to the "maximum" individual, 1970

Composite estimates of radiation dose

The "maximum" individual

Exposure accumulated from the environmental surveillance program and associated research studies has indicated that those individuals receiving the greatest percentage of permissible radiation dose standards from Hanford sources consumed some combination of the following: fish caught locally in the Columbia River, gamebirds shot near the river, foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors, and municipal water with the Columbia River as its source. A hypothetical "maximum" individual has been assigned assumed dietary habits which are identical to those used in the 1966 through 1969 annual reports (*1–3,17*). The consumption rates of most foods for this hypothetical "maximum" individual were compiled from intake rates described in published dietary surveys and have been documented separately in detail (*18,19*).

The composite doses estimated for this "maximum" individual for 1970 are shown graphically in figure 7 and summarized in table 16. Major decreases from the 1969 values were noted for all estimated organ doses.

1970 dose estimates for bone, whole body, and GI tract of the "maximum" individual continued to be predominantly from external exposure while fishing plus the consumption of Columbia River fish. The relative contributions from other pathways were greater than in the past, as radioactivity in the river declined with successive reactor shutdowns. The "maximum" individual thyroid dose declined even more sharply in 1970 due to the reduction in radioiodines released to the river in reactor effluents. The composite annual doses for 1967 through 1970 are shown in table 17.

The "average" Richland resident

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in previous reports (*3,19*). Not only are quantities consumed smaller than for the hypothetical "maximum" individual, sources of food, milk, and water based on the survey data indicate much greater dependence on commercial sources.

Table 16. Summary of annual radiation doses[a] in the Hanford environs, 1970

Organ	Dose standard (mrem)	Calculated dose (mrem)	Percent of standard
Maximum individual:			
Bone	1 500	94	6
Whole body	500	12	2
GI tract	1 500	27	2
Thyroid (infant)	1 500	30	2
Average Richland resident:			
Bone	500	9	2
Whole body	170	2	1
GI tract	500	12	2
Thyroid (infant)	500	8	2

[a] Doses from fallout and natural background not included.

Table 17. Comparable dose estimates for maximum individual and average Richland resident, 1967–1970[a]

Organ	Percent of standard				Dose standard (mrem/yr)
	1967	1968	1969	1970	
Maximum individual:					
Bone	26	17	9	6	1 500
Whole body	6	5	4	2	500
GI tract	5	4	3	2	1 500
Thyroid (infant)	6	7	4	2	1 500
Average Richland resident:					
Bone	5	3	3	2	500
Whole body	3	2	2	1	170
GI tract	6	5	4	2	500
Thyroid (infant)	8	8	5	2	500

[a] Not including contributions from fallout or natural background radiation.

In computing doses for the "average" Richland resident, the assumed sources were Richland drinking water (with average concentrations adjusted for radioactive decay and dilution), Columbia River fish (with the average species composition of fish ingested by the "maximum" individual, but a much smaller quantity), an average species mix of gamebirds, and average amounts of milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the ambient radiation levels in Richland has been discerned in the past, the external dose to the "average" Richland resident was assumed to result only from recreational use of the Columbia River. An

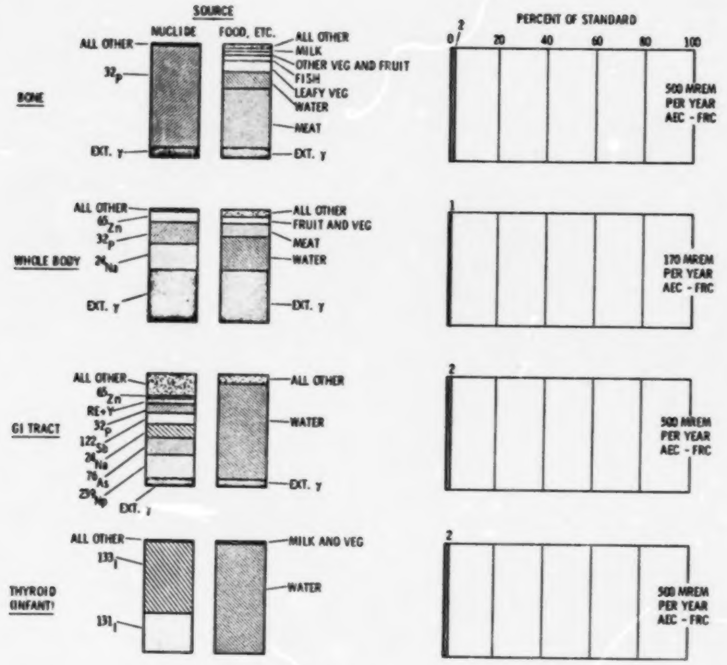

Figure 8. Estimated doses to the "average" Richland resident, 1970

estimated annual dose increment of 2 mrem from immersion in the river and activities along the shoreline was included in the GI tract, whole body, and bone doses. No such increment was included in the thyroid dose, calculated for an infant, because of the limited use of the river by this age group.

The composite doses estimated for the "average" Richland resident for 1970 are displayed in figure 8 and summarized in table 15. All 1970 doses estimated for the "average" Richland resident, like those for the "maximum" individual, decreased significantly with reduced radioactivity in the river and associated pathways.

For the "average" Richland resident, consumption of drinking water was by far the most important source of radiation dose. Because of the broad spectrum of radionuclides in the drinking water, however, no one radionuclide predominated as a dose contributor to all organs.

The trend of exposure to the "average" Richland resident over the 1967–1970 period also is shown in table 17.

Conclusions

The 1970 Hanford environmental surveillance program indicated continued compliance of the Hanford contractors and their operations with applicable environmental standards. Most of the environmental radiation dose for people living in the Hanford environs was due to natural sources and regional fallout rather than to Hanford operations. Although much reduced from previous years, the largest source of radioactivity released to man's immediate environment from Hanford continued to be reactor cooling water discharged to the Columbia River.

The basic standards for evaluating the adequacy of radiological control at Hanford are taken to be radiation doses to specified population groups, as given in AEC Manual, Chapter 0524 (*20*).

The surveillance program included sampling and analysis on a routine basis of river water, municipal drinking water, groundwater, air, milk, foodstuffs, fish, shellfish, and gamebirds.

Measurements were made of external gamma exposure rates at land stations, in the river, over the river surface, and along the river shoreline. Contamination surveys were made at selected plots and along public highways adjacent to the Hanford site.

Shutdown in February 1970, of KW reactor, one of the two remaining single-pass, river water-cooled production reactors, as well as an extended shutdown of all reactors, greatly reduced the major remaining source of population exposure from Hanford operations. In 1970, average river concentrations of radionuclides were less than 3 percent of the AEC standards, and transport rates of radionuclides in the river were much reduced from 1969. The radionuclide showing the highest average percentage of its AEC standard in treated water at the Richland water plant was sodium–24 at 2.1 percent. Reductions from 1969 values were seen in radionuclide concentrations in Columbia River fish, shoreline radiation levels, and direct radiation measurements of the river.

Groundwater contamination originating in the chemical separations areas showed no appreciable advance toward the Columbia River. Tritium in groundwater around N reactor area may have contributed to an apparent small increase measured in river tritium concentration between Vernita and Richland, but the average downstream concentration from all sources, including weapons test and natural formation, was less than .05 percent of the AEC standard.

Airborne radioactivity measurements continued to show the occasional presence of fallout from weapons testing. Particulate radioactivity concentrations around the site perimeter, however, were essentially the same as at more distant locations, indicating a lack of contribution from Hanford sources. Land-based gamma radiation measurements showed the same pattern, with a small increase from 1969 to 1970. Radioiodines were not detected in air or milk samples except during a fallout occurrence.

Unusually high concentrations of phosphorus–32 were found in 4 of 15 ducks collected at 2 trenches receiving undiluted reactor cooling water. Immediate consumption of a normal meal of the duck with the highest phosphorus–32 concentration in muscle, 0.14 μCi/g, could theoretically have resulted in a radiation dose to skeletal bone of about 6 rem, four times the applicable standard. However, based on hundreds of ducks collected during years of routine sampling along the river and nearer public hunting areas, radionuclide concentrations in ducks resident for extended periods on open water around the plant facilities are not representative of those birds likely to be taken and consumed by the public. Corrective action was taken to prevent any further access by waterfowl to the trenches.

As in past years, annual radiation doses resulting from Hanford operations were calculated for the bone, whole body, GI tract, and thyroid for both a hypothetical "maximum" individual and the "average" Richland resident. During 1970, calculated doses of Hanford origin were all much less than one-tenth of the applicable dose standards, reflecting a general and significant decrease from comparable 1969 values.

The hypothetical "maximum" individual postulated to receive the largest plausible dose from Hanford sources is assumed to have the following sources of exposure:

200 meals of fish caught downstream from the reactors,

500 hours on the river shoreline catching the fish,

milk, meat, and produce in season from farms irrigated with river water, and

drinking water from a municipal water supply taken from the river.

For 1970, the annual skeletal bone dose for this "maximum" individual was calculated as 94 mrem, or 6 percent of the applicable standard of 1 500 mrem. Doses to both the GI tract and the whole body were estimated to be about 2 percent of the respective standards.

For thyroid dose estimates, an infant with a 2-gram thyroid, consuming milk and some vegetables from river-irrigated farms, was considered the "maximum" individual. Dietary habits postulated for such an infant could have resulted in an annual dose to the thyroid of about 2 percent of the standard of 1 500 mrem.

The "average" Richland resident also is defined as an adult for estimation of bone, whole body, and GI tract doses, and as an infant for estimation of thyroid dose. The dietary and recreational habits of the "average" Richland resident have been determined from local surveys. The small radiation doses received by this population group in 1970 from Hanford operations continued to originate in most part from radionuclides discharged to the Columbia River in reactor cooling water and taken into the Richland municipal supply. For dose estimation, radionuclide concentrations measured at the Richland water treatment plant were adjusted for dilution and radioactive decay in the water distribution system. For 1970, the calculated GI tract and bone doses were 2 percent of the standard of 500 mrem per year for this population group. The whole body dose was estimated to be about 1 percent of the standard of 170 mrem per year. The thyroid dose to the average Richland infant was calculated to be about 2 percent of the standard of 500 mrem per year.

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Reported Nuclear Detonations, March 1974

(Includes seismic signals presumably from foreign nuclear detonations)

There were no reported nuclear detonations for the United States for March 1974 and no recorded seismic signals for this month.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

MICROWAVE HAZARD MEASUREMENTS NEAR VARIOUS AIRCRAFT RADARS. *Richard A. Tell* and *John C. Nelson. Radiation Data and Reports, Vol. 15, April 1974, pp. 161–179.*

In order to determine the potential for exposure of individuals when in the vicinity of aircraft radar units when aircraft are on the ground, the Electromagnetic Radiation Analysis Branch monitored four radar units that were typical of radars used by commercial aircraft. Two of the units were surveyed at a radar simulation laboratory and the other units were surveyed while in their operating positions in aircraft.

The survey determined that the radar beams from navigational and weather radar units in commercial aircraft rotate in either a sector-scanned or 360 degree rotation at approximately 15 r/min. The radar beams emanated from the aircraft above 6 feet from the ground. It was determined that power density exposures of 10 mW/cm can occur from 8 to 18 feet from the antenna of an aircraft radar unit.

No radiation levels in excess of 0.2 mW/cm^2 existed in the aircraft cockpits.

KEYWORDS: Aircraft, microwave, radar, radiation.

RADIATION DATA AND REPORTS

Volume 15, Number 5, May 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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- Department of Agriculture
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- Department of Health, Education, and Welfare
- Environmental Protection Agency
- Atomic Energy Commission

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

Reports

Environmental and Radiological Monitoring at the National Reactor Testing Station During FY-1973 (July 1972–June 1973)

O. Doyle Markham[1]

The routine environmental monitoring program at the National Reactor Testing Station (NRTS) during FY-1973 is described. In addition to the measurement of direct radiation exposures in the environment, the concentrations of radioactivity in air, groundwater, and milk also are determined. The results of a soil sampling program are discussed. The data from onsite and nearby community sampling locations are compared to background concentrations and the applicable standards established by the U.S. Atomic Energy Commission.

In addition, several special ecological monitoring programs have been designed to assess the effect of NRTS operations on the environment. One of the ecological studies quantifies the level of radioactivity in antelope tissues collected on and near the NRTS. An investigation to ascertain the ratio of iodine-129 to stable iodine-127 in the NRTS environs also is described.

This report describes results of the environmental monitoring program conducted by the Health Services Laboratory at the National Reactor Testing Station (NRTS). The Health Services Laboratory (HSL) is a division of the Idaho Operations Office, U.S. Atomic Energy Commission (AEC).

The National Reactor Testing Station is located in the upper Snake River Plain in southeastern Idaho. The station consists of 571 800 acres (approximately 2286 km^2 or 893 square miles) which extends almost 63 km (39 miles) north to south and about 58 km (36 miles) east to west at its broader southern part. The reservation includes portions of Butte, Bingham, Bonneville, Jefferson and Clark Counties. Several small communities are situated adjacent to the boundaries of NRTS (figure 1). Arco, the largest of these with a 1970 population of 1244 is 11 km (7 miles) west of the site boundary. Located near the northwestern border is Howe, with Mud Lake and Terreton to the northeast. The largest town in the area, Idaho Falls, with a population of approximately 36 000 is 47 km (29 miles) east of the site boundary.

The upper Snake River Plain is representative of the cool desert shrub biome. Sagebrush-grass communities are dominant on the site but other vegetative communities are important locally. Associated with the various vegetative types is a varied animal component, encompassing most of the reptiles, birds, and mammals associated with this biome.

Most of the land surrounding the site boundary is undeveloped. This land, as well as portions of the site, is utilized for sheep and cattle grazing. Most of the nearby farming is concentrated in areas north and northeast of the station. Larger farming areas are situated at a greater distance from the NRTS in the Snake River Valley.

The NRTS was established in 1949 to provide a location where the AEC could build, test, and operate various types of nuclear reactors and allied plants and equipment. Since that time, 50 reactors have been constructed at the NRTS. Sixteen of these reactors presently are operating or capable of operating. Table 1 and figure 1 indicate acronyms and locations for the various NRTS facilities.

---

[1] Dr. Markham is a Radioecologist with the Environmental Sciences Branch, Health Services Laboratory, U.S. Atomic Energy Commission, Idaho Operations Office, Idaho Falls, Idaho 83401.

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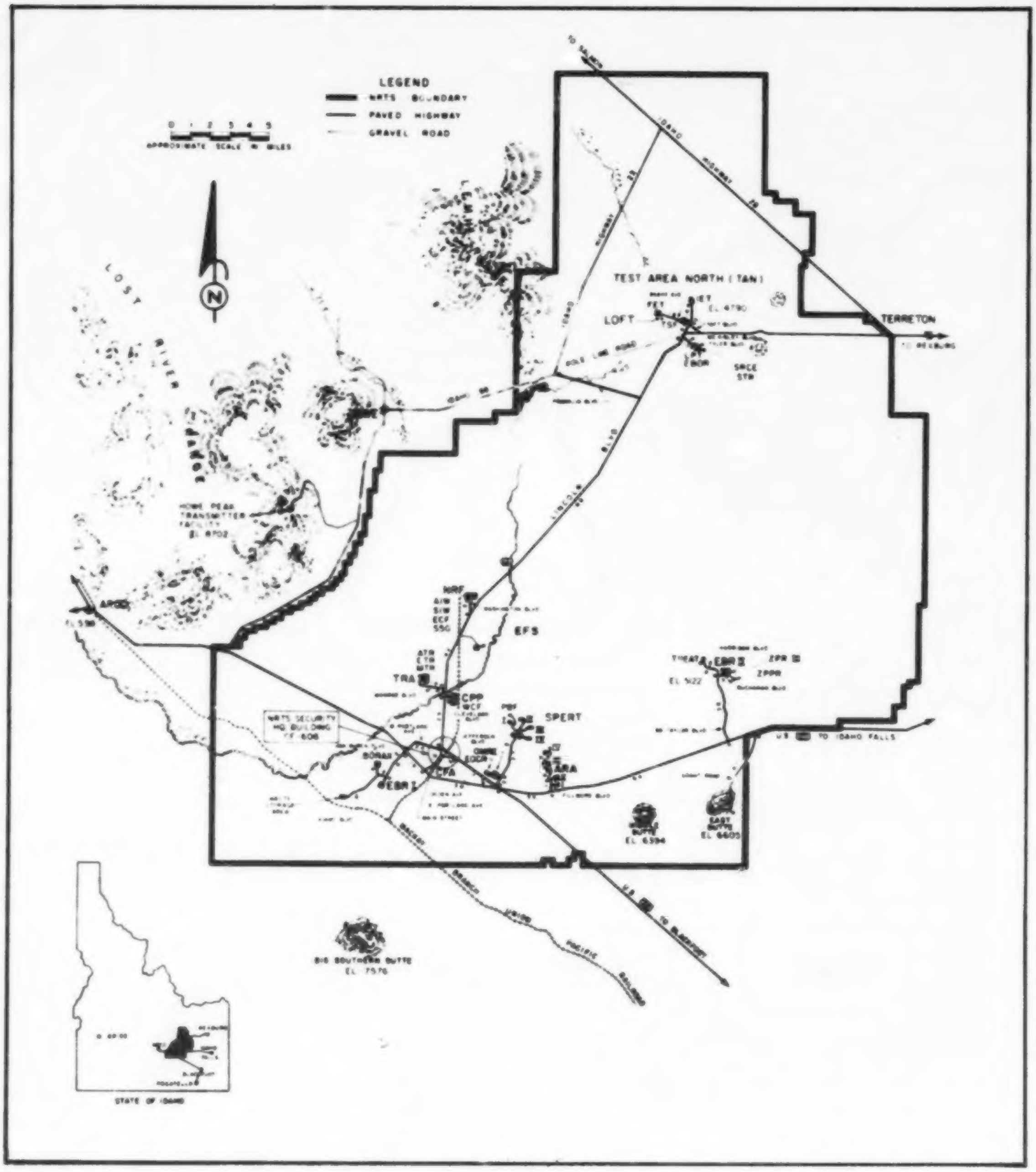
LEGEND
NRTS BOUNDARY
PAVED HIGHWAY
GRAVEL ROAD
0 1 2 3 4 5
APPROXIMATE SCALE IN MILES
N
LOST RIVER RANGE
TO SALMON
IDAHO HIGHWAY 28
IDAHO HIGHWAY 33
TEST AREA NORTH (TAN)
LOFT
FET
IET
TSF
EBOR
EL 4790
SPCE STR
TERRETON
TO REXBURG
POLE LINE ROAD
IDAHO 88
LINCOLN BLVD
HOWE PEAK TRANSMITTER FACILITY EL 8702
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ATR
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MTR
TRA
CPP
WCF
NRTS SECURITY HQ BUILDING CF 606
BORAX
CFA
EBR I
PBF
SPERT
I
II
III
IV
OMRE
EOCR
ARA
TREAT
EBR II
ZPR III
ZPPR
EL 5122
U.S. 20 TO IDAHO FALLS
MIDDLE BUTTE EL 6394
EAST BUTTE EL 6605
U.S. 26 TO BLACKFOOT
ARCO BRANCH UNION PACIFIC RAILROAD
BIG SOUTHERN BUTTE EL 7576
STATE OF IDAHO
REXBURG
IDAHO FALLS
BLACKFOOT
POCATELLO

Figure 1. National Reactor Testing Station location and NRTS facility locations

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Table 1. Tabulation of facilities at the NRTS

Reactors operating or operable	Abbreviation
1. Engineering Test Reactor	ETR
2. Experimental Breeder Reactor No. 2	EBR–II
3. Large Ship Reactor "A"	A1W–(A)
4. Large Ship Reactor "B"	A1W–(B)
5. Submarine Thermal Reactor	S1W–(STR)
6. Transient Reactor Test Facility	TREAT
7. Argonne Fast Source Reactor	AFSR
8. Engineering Test Reactor Critical [a]	ETRC
9. Advanced Reactivity Measurement Facility No. 1	ARMF–I
10. Advanced Test Reactor Critical [a]	ATRC
11. Natural Circulation Reactor	S5G
12. Advanced Test Reactor	ATR
13. Split Table Reactor [a]	STR
14. Coupled Fast Reactor Measurement Facility [a]	CFRMF
15. Zero Power Plutonium Reactor [a]	ZPPR
16. Power Burst Facility	PBF
Reactors dismantled, transferred, or in standby status	
1. Boiling Water Reactor No. 1	BORAX–I
2. Boiling Water Reactor No. 2	BORAX–II
3. Boiling Water Reactor No. 3	BORAX–III
4. Boiling Water Reactor No. 4	BORAX–IV
5. Heat Transfer Reactor Experiment No. 1	HTRE–I
6. Heat Transfer Reactor Experiment No. 2	HTRE–II
7. Heat Transfer Reactor Experiment No. 3	HTRE–III
8. Shield Test Pool Facility Reactor [a]	SUSIE
9. Critical Experiment Tank [a]	CET
10. Hot Critical Experiment [a]	HOTCE
11. Stationary Low Power Reactor No. 1 [b]	SL–1
12. Reactivity Measurement Facility [a]	RMF
13. Gas Cooled Reactor Experiment	GCRE
14. Organic Moderated Reactor Experiment	OMRE
15. Experimental Organic Cooled Reactor (mothballed before startup)	EOCR
16. Experimental Breeder Reactor No. 1	EBR–I
17. SNAP 10A Transient No. 3	SNAPTRAN–3
18. Special Power Excursion Reactor Test No. 1	SPERT–I
19. Boiling Water Reactor No. 5	BORAX–V
20. High Temperature Marine Propulsion Reactor [a]	630–A
21. SNAP 10A Transient No. 1	SNAPTRAN–1
22. Mobile Low Power Reactor No. 1 (Army)	ML–1
23. SNAP 10A Transient No. 2	SNAPTRAN–2
24. Experimental Beryllium Oxide Reactor	EBOR
25. Fast Spectrum Refractory Metals Reactor	710
26. Advanced Reactivity Measurement Facility No. 2	ARMF–II
27. Materials Test Reactor	MTR
28. Special Power Excursion Reactor Test No. 2	SPERT–II
29. Special Power Excursion Reactor Test No. 3	SPERT–III
30. Special Power Excursion Reactor Test No. 4	SPERT–IV
31. Zero Power Reactor No. 3 [a]	ZPR–III
32. Cavity Reactor Critical Experiment [a]	CRCE
33. Nuclear Effects Reactor [a]	FRAN
34. Spherical Cavity Reactor Critical Experiment	SCRCE
Other facilities in use	
1. Auxiliary Reactor Area	ARA
2. Idaho Chemical Processing Plant	ICPP
3. Expended Core Facility	ECF
4. Fuel Element Storage Facility	FESF
5. Gamma Irradiation Facility	GIF
6. Health Services Laboratory	HSL
7. Chemical Engineering Laboratory	CEL
8. Waste Calcining Facility	WCF
9. Field Engineering (formerly Flight Engine Test) Facility	FET
10. Low Power Test Facility	LPTF
11. Test Area North	TAN
12. Technical Services Center (CF–688–689)	TSF
13. Central Facilities Area	CFA
14. Naval Reactor Facility	NRF
15. Test Reactor Area	TRA
16. Technical Services Facility	TSF
17. Experimental Field Station	EFS
18. Hot Pilot Plant	HPP
19. Shield Test Pool Facility (adapted for EBOR)	STPF
20. Gas Cooled Reactor Facility	GCRF
21. Reactor Training Facility	RTF
22. Computer Science Center (in Idaho Falls)	CSC
23. Fuels and Examination Facility	FEF
24. Radioactive Storage Area	RSA
25. Hot Fuel Examination Facility	HFEF
26. Initial Engineering Test Facility	IET
Reactors under construction	
1. Loss-of-Fluid Test Facility	LOFT

[a] Zero or low power reactor.

[b] Accidentally destroyed during shutdown, January 3, 1961, following 931.5 megawatt days of successful operation.

Currently, emphasis is placed on several major programs. One program provides test irradiation services from two high-flux reactors, the Engineering Test Reactor (ETR) and Advanced Test Reactor (ATR). The Idaho Chemical Processing Plant (ICPP) recovers uranium from highly enriched spent fuels and solidifies and stores the resultant radioactive waste. The Loss-of-Fluid Test (LOFT) and the Power Burst Facility (PBF) are major projects in the light-water-cooled reactor safety program. The Experimental Breeder Reactor II (EBR-II) is the only operating Liquid Metal Fast Breeder Reactor in the United States. Other significant programs include the operation of the Naval Reactor Facility (NRF) and storage at the Radioactive Storage Area of fission and activation waste from the NRTS and transuranic waste from the Commission's Rocky Flats activities.

Along with the routine monitoring program (external radiation, soil, water, air, milk, and wheat) conducted by the Health Services Laboratory, the U.S. Geological Survey (USGS) monitors the aquifer through periodic sampling of wells on and near the NRTS. In addition, several special studies have begun under a recently initiated NRTS radioecology program. This program provides both one-time and continuous studies of the ultimate fate of radioactive pollutants in the environs.

Atmospheric monitoring

The atmospheric monitoring program provides specific radionuclide identification and surveillance of the gross alpha, gross beta and strontium-90 in air at onsite, boundary and distant background sampling locations.

At each of eight onsite, six boundary, and three background locations (figure 2), continuous air samplers maintain an average air flow of approximately 28 liters/minute through a set of filters. A membrane particle prefilter (Gelman Model AN–800) is followed by an activated charcoal-impregnated cellulose fiber filter (Gelman Model AC–1) for radioiodine collection. In order to permit the short-lived radon and thoron daughters to decay, the filters are analyzed a minimum of 5 days after completion of each 1-week sampling period. The membrane filter is analyzed for gross alpha and gross beta activity and the AC–1 filter is analyzed for gross beta activity. All analyses utilize low background counting systems. All activity detected on the AC–1 filters is assumed to be iodine-131. Each quarter, composite particulate filters from each of several selected locations are analyzed for gamma-emitting nuclides by gamma spectrometry and for strontium-90 by wet chemistry methods. Gross alpha activity analysis was discontinued after FY-1973 and has been replaced by analysis for specific alpha emitters using wet chemistry and alpha spectrometry. In addition to the 17 weekly air samplers, filters on two high volume air samplers are changed each work day. Each of these daily samplers is equipped with a 4-inch diameter BM–2133 cellulose fiber filter impregnated with charcoal. These samplers located at CFA and EFS draw an average of 1230 liters of air per minute through the filters. These two samplers provide an early warning of any significant release. The filters are gross gamma counted immediately after collection and periodically during the first 24 hours after collection to observe the radioactive decay rate of the collected radioactivity. Decay rates slower than those expected for the naturally occurring radon and thoron daughters indicate that other nuclides were collected and additional analyses are performed to evaluate specific radionuclide concentrations in the sampled air. The gross gamma analysis is used for daily checking of activity levels in the atmosphere and is not intended to provide a permanent record of airborne radioactivity.

Starting in mid-February 1973, tritium sampling in the atmosphere began at the EFS and at another location on Lincoln Boulevard approximately 2 km south of ICPP (figure 1). Water vapor is collected as air is pumped through a silica gel desiccant at a rate of 0.28 liters/min. After each 2-week collection period, the silica gel is heated in the laboratory, and the resultant water vapor is condensed and analyzed for tritium in a liquid scintillation counter.

The maximum tritiated moisture concentrations were 24 pCi/m^3 of air at the EFS and

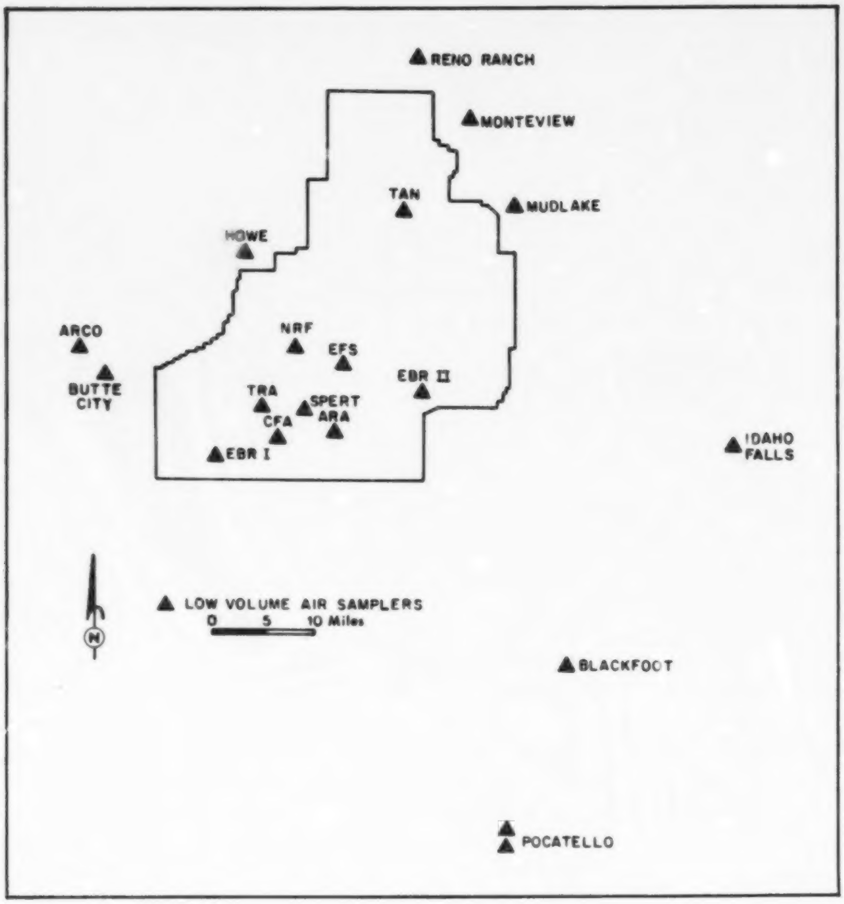

Figure 2. NRTS onsite and offsite air monitoring network (EFS monitoring station installed late in FY 1973)

44 pCi/m^3 of air at Lincoln Boulevard station. The average concentration for both sampling stations was less than 11 pCi/m^3. The highest was 2.2×10^{-2} percent of the AEC concentration guide value of 200 nCi/m^3 for an individual in an uncontrolled area (*1*).

The gross alpha, gross beta, and iodine-131 determinations for the air monitoring stations are summarized in table 2. The average gross alpha concentrations were 1.7 fCi/m^3 for the six boundary stations and 1.6 fCi/m^3 for the eight onsite stations. Due to the release of naturally occurring alpha emitters as a result of fossil fuel combustion from fertilizer manufacturing processes, the gross alpha concentrations at the background locations of Idaho Falls, Blackfoot, and Pocatello were not representative of the NRTS background; therefore, a comparison to background levels is not attempted. However, if significant onsite releases of alpha activity were occurring, gross alpha air concentrations for at least one and most likely several of the onsite stations would be higher than the concentrations in the boundary communities. Since this was not observed, it is concluded that the gross alpha concentrations measured at the onsite and boundary stations did not result from NRTS related activities.

The average gross beta concentrations were 110 fCi/m^3 for onsite stations, 100 fCi/m^3 for boundary communities and 100 fCi/m^3 for background stations. The highest onsite aver-

Table 2. Summary of atmospheric monitoring in the vicinity of the National Reactor Testing Station during FY–1973

Sampling location	Gross alpha concentration [a] (fCi/m³)		Gross beta concentration [b] (fCi/m³)		Iodine-131 concentration [c] (fCi/m³)	
	Maximum	Average	Maximum	Average	Maximum	Average
Onsite:						
EBR–I	3.1	1.4± 0.5	1 040	130±160	21	<10
CFA	2.3	1.5± .5	580	120±120	22	<10
TRA	3.9	1.7± .7	540	120±110	76	<10
NRF	2.6	1.5± .6	490	100±100	38	<10
TAN	3.1	1.5± .6	420	100± 90	25	<10
SPERT	4.0	1.5± .6	530	100±110	33	<10
ARA–II	3.6	1.4± .5	410	90± 70	13	<10
EBR–II	4.0	1.7± .7	460	100± 90	18	<10
Boundary:						
Mud Lake	7.8	1.9± .9	580	110±110	13	<10
Howe	3.6	1.7± .7	450	100±100	26	<10
Butte City	3.1	1.5± .5	500	100±100	10	<10
Reno Ranch	3.2	1.4± .6	500	100±100	32	<10
Arco	3.8	1.7± .7	460	100± 90	23	<10
Monteview	3.6	1.6± .6	340	80± 70	54	<10
Background:[d]						
Blackfoot	3.9	2.3± .8	490	100±100	10	<10
Idaho Falls	4.8	2.5± .8	410	90± 80	23	<10
Pocatello	81.1	16.8±15.0	470	100± 90	29	<10

[a] The AEC concentration guide value (*1*) for gross alpha exposure to an individual in an uncontrolled area is 20 fCi/m³ of air.

[b] The AEC concentration guide value (*1*) for gross beta exposure to an individual in an uncontrolled area is 1000 fCi/m³ of air.

[c] The AEC concentration guide value (*1*) for iodine-131 exposure to an individual in an uncontrolled area is 100 pCi/m³ of air.

[d] Gross alpha concentrations at these locations are not representative of the NRTS background due to the presence of the naturally occurring nuclide, polonium-210, released by the burning of fossil fuels and other industrial activity. The concentration guide value for polonium-210 for the general population is 2 pCi/m³.

age concentrations measured, 130 fCi/m³ at EBR–I, was well below the guide value of 1 pCi/m³ for an individual in an uncontrolled area. The highest average boundary concentration, measured at Mud Lake, was lower than the guide value.

Although the overall onsite average was only slightly above the background average, several onsite stations had average concentrations above the background average of 100 fCi/m³. The highest average concentration at an onsite station, EBR–I, was 36 percent above the background level. (EBR–I is not an operating facility, but is in a predominant downwind direction from the ICPP.) These higher average values for onsite stations were the result of atmospheric releases by NRTS facilities, primarily the ICPP. During FY-1973, over 99 percent of the long-lived particulate activity released to the atmosphere from NRTS facilities originated from the ICPP (*2*).

The weekly gross beta concentration data for EBR–I and the average of the weekly data from the background stations (Blackfoot, Pocatello, Idaho Falls) were compared by a two factor analysis of variance with weekly periods and the two sampling stations (EBR–I and background average) as sources of variation. The analysis indicated statistically significant effects due to sampling period ($\alpha < 0.005$) and sampling stations ($\alpha = 0.025$). When the highest boundary location, Mud Lake, was compared in a similar analysis to offsite averages, the station effect was not a significant contribution to the variability ($F = 1.3$; $DF = 1, 51$). However, the weekly sampling periods did contribute significantly to the variability ($\alpha < 0.005$). This would indicate that the gross beta air concentrations at EBR–I were significantly higher than background due to NRTS atmospheric releases of radioactivity, but the gross beta air concentrations at Mud Lake were not different from background concentrations. The analysis also indicates that the variability of the data is related to the weekly sampling periods. This weekly variability is related to variability in worldwide fallout and also to seasonal and weather conditions.

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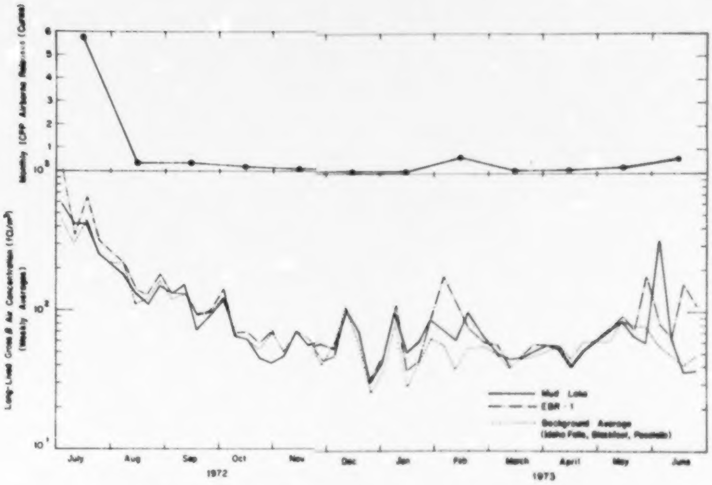

Figure 3. Weekly average long-lived gross beta air concentrations from EBR–I, Mud Lake, and the average of background air monitoring stations compared to monthly ICPP (nongaseous) release data

When the EBR–I and Mud Lake gross beta concentrations are graphically compared to the background average concentration (figure 3), the beta air concentration at Mud Lake and EBR–I appear to be relatively higher than background determinations during July, February, and June. These above background peaks appear to correlate with ICPP atmospheric release data which indicate that relatively larger releases of radioactivity occurred in July, February, and June than during the other months (figure 3). During July, more airborne radioactivity was released from ICPP than during February and June. However, the difference between background and the Mud Lake data was not as great as the difference observed in February and June. This condition may have been the result of the higher worldwide fallout in July (due to a recent atmospheric test) that masked the relatively low NRTS contribution.

Therefore, it appears that the average onsite gross beta air concentration at some locations during FY-1973 was higher than background levels as a result of NRTS atmospheric releases. However, the gross beta air concentrations at the boundary communities were not different from that which occurred in the background areas. Small amounts of activity resulting from NRTS activities were detected at least at one boundary community (Mud Lake), but the NRTS contribution at this location was so minute that it did not significantly alter the average air concentration.

The iodine-131 concentrations were near or below the minimum detection limits for the analysis (table 2). The highest onsite observation was 76 fCi/m³ at TRA and the highest offsite determination, 54 fCi/m³, occurred at Monteview. Both maximums were recorded in July during the passing of fallout from nuclear atmospheric testing. Both maximums were a small fraction of the guide value of 100 pCi/m³ (assuming that the exposure is due to inhalation only and not via the milk-food chain) for an individual in an uncontrolled area (*1*).

Further evidence for the low levels of activity in air can be seen in the data tabulated from the gamma spectra and strontium-90 analysis of the quarterly composites of the weekly air filters (table 3). Only during the first quarter of FY-1973 were any gamma-emitting nuclides detected in the filters above the minimum detection limits. During the first quarter, levels of activity in the air were relatively higher at all locations (figure 3) because of the increased worldwide fallout. The detected nuclides in the first quarter composite filters most likely are due to this relatively higher

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Table 3. Results of gamma spectra analyses and strontium-90 analyses of quarterly composites of weekly air filters at the National Reactor Testing Station, FY 1973

Analysis	Offsite air concentrations (fCi/m³)						Onsite air concentrations (fCi/m³)	
	Idaho Falls		Butte City		Mud Lake		EBR–I	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Antimony-125	([a])	([a])	11	([b])	([a])	([a])	5	([b])
Cesium-137	3	([b])	14	([b])	7	([b])	5	([b])
Zirconium-95	5	([b])	7	([b])	6	([b])	([a])	([a])
Niobium-95	83	([b])	13	([b])	6	([b])	([a])	([a])
Strontium-90	6	3	3	2	3	2	6	3
Cerium-141	2	([b])	([a])	([a])	([a])	([a])	5	([b])
Cerium-144	12	([b])	([a])	([a])	15	([b])	23	([b])
Ruthenium-103	4	([b])	([a])	([a])	3	([b])	5	([b])

[a] Below detection limit. Detection limits varied because of different air flow volumes and counting times.

[b] A meaningful average could not be computed; the radionuclide was detected in only one quarterly composite sample.

worldwide fallout. Strontium-90 determinations were similar at both onsite and background stations and also are believed to be the result of worldwide fallout. The highest strontium-90 concentrations occurred at EBR–I and Idaho Falls. These concentrations were a small fraction of the guide value of 30 pCi/m³ for an individual in an uncontrolled area.

Calculations show that the maximum 1972 whole body dose to an individual in an offsite population resulting from direct exposure or to inhalation of NRTS radioactive atmospheric effluents (both gaseous and particulates) was 1.5 mrem. The computed exposure to the population (66 918) residing within 80 km (50 miles) of the NRTS during 1972 was 2.4 man-rem (*3*).

Monitoring of external radiation

In order to determine any addition from NRTS facilities to the natural background gamma and x-radiation exposure levels, thermoluminescent dosimeters (TLD) are employed at various onsite facilities as well as boundary and background or control communities (figure 4).

The TLD's consist of 3.18 mm × 3.18 mm × 0.89 mm thick Harshaw TLD–700 LiF chips. Each series of five chips was enclosed by 0.76 mm thick plastic and inserted into a steel dosimeter badge holder. The chips were positioned under an open window covered with waterproof tape. Generally, one badge with five chips was positioned approximately 1 meter above the ground surface at each onsite location. Five badges or a total of 25 LiF chips were utilized at each boundary community location and a total of 10 LiF chips was placed at the background locations. (The steel dosimetry badges no longer are used; instead beginning in May 1973, the LiF chips are attached to a paper card, covered by aluminized mylar punch tape and laminated with 0.25 mm thick plastic and inserted into a 5 × 10 cm card holder for field deployment.) The sampling stations are operated on a 6-month-exchange schedule. Generally, the TLD stations around NRTS facilities are located at regular intervals near the exclusion fences which surround these facilities. The TLD's on U.S. Highway 20, which crosses the site, are located at 2-mile intervals as are the TLD's on Lincoln Boulevard/Idaho Highway 88, the main NRTS north-south highway.

The chips are analyzed with a Model 2000 Harshaw Thermoluminescent Detector. The readings are compared to those from identical calibration LiF chips which received known exposures from a radium-226 source. The average boundary exposure (table 4), 146 ± 12 mR was not significantly different from the average background exposure of 156 ± 13 mR. This indicates that the exposures at the boundary

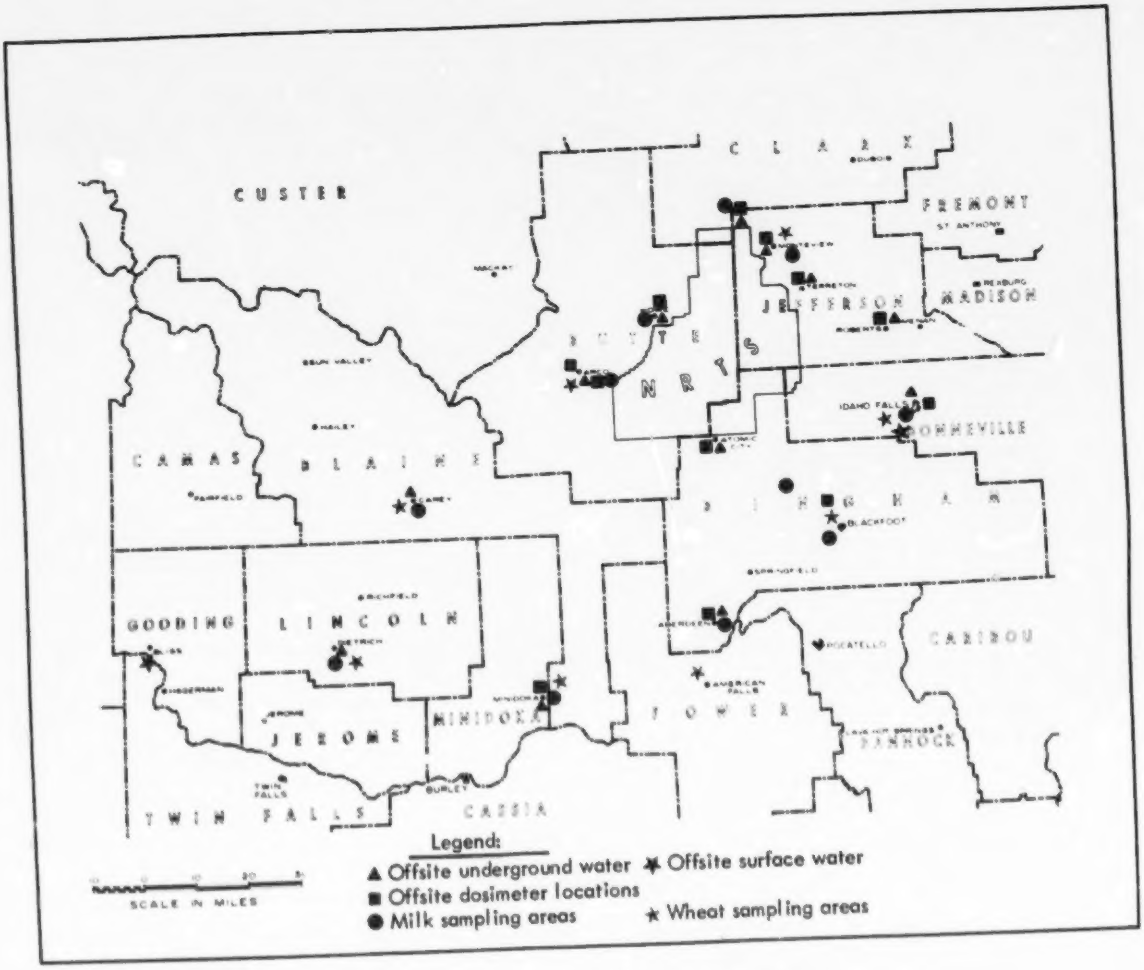
CUSTER
CLARK
DUBOIS
FREMONT
ST. ANTHONY
REXBURG
MADISON
JEFFERSON
MONTEVIEW
TERRETON
ROBERTS
MACKAY
BUTTE
ARCO
NRTS
SUN VALLEY
HAILEY
CAMAS
FAIRFIELD
BLAINE
CAREY
IDAHO FALLS
BONNEVILLE
ATOMIC CITY
BINGHAM
BLACKFOOT
SPRINGFIELD
GOODING
LINCOLN
RICHFIELD
DIETRICH
BLISS
HAGERMAN
JEROME
MINIDOKA
ABERDEEN
POCATELLO
CARIBOU
AMERICAN FALLS
POWER
LAVA HOT SPRINGS
BANNOCK
TWIN FALLS
BURLEY
CASSIA
SCALE IN MILES
Legend:
▲ Offsite underground water
■ Offsite dosimeter locations
● Milk sampling areas
✱ Offsite surface water
★ Wheat sampling areas

Figure 4. Offsite sampling stations, NRTS

locations are due to natural terrestrial and solar radiation and not due to NRTS activities. The variation among exposures from different locations indicates the variability of these natural sources.

Onsite average exposures were higher in the EBR–II, TRA, ARA I & II, RSA, ICPP, and CFA areas. These higher values were due to one or more of the following factors: operation of a facility, storage of radioactive waste, or the presence of radioactivity in evaporation ponds. In the ICPP and ARA areas, part of the exposures may be due to surface radioactive contamination around the facilities. The higher CFA average exposure resulted from a monitoring station near the Health Services Laboratory. This station documents exposures from a radioactive storage vault and a calibration source inside the laboratory near the TLD station.

Soil sampling

In order to establish levels in the soil and to assess any long-term buildup of activity, soil samples were collected from several onsite, boundary, and background locations during 1971 (figure 5). Generally onsite samples were collected from locations 0.5 to 1.6 km northeast and southwest of various NRTS facilities

Table 4. Summary of thermoluminescent dosimeter exposure data from the National Reactor Testing Station, boundary and background control locations. (May 1972 to May 1973)

Area	Sampling locations	Number of TLD's at each location	Exposure (mR/year)
Onsite:			
ARA-I & II	4	5	500 ± [a]400
SPERT	6	5	145 ± 7
CFA	3	5	200 ± 100
RSA	18	5	1400 ± 2000
U.S. Hwy 20	[b]10	5	140 ± 20
Lincoln Blvd/Hwy 88	13	5	150 ± 10
EBR-II	[b]8	5	200 ± 100
TREAT	2	5	135 ± 6
TSF	1	5	166 ± 6
LOFT	3	5	144 ± 7
LPTF	4	5	135 ± 5
NRF	11	5	160 ± [illegible]
ICPP	13	5	500 ± [illegible]00
TRA	13	5	1600 ± 1900
EBR-I	1	25	160 ± 8
Boundary:			
Howe	1	25	[c]135 ± 5
Monteview	1	25	139 ± 5
Reno Ranch	1	25	136 ± 5
Atomic City	1	25	170 ± 10
Arco	1	25	144 ± 4
Butte City	1	25	[illegible]50 ± 6
Mud Lake	1	25	14[illegible] 6
Background:			
Minidoka	1	10	143 ± 5
Aberdeen	1	10	173 ± 9
Roberts	1	10	160 ± 10
Blackfoot	1	10	151 ± 6

[a] Standard deviation (SD) of the mean of the exposure at different locations near each facility.

[b] This area had one less location during the first 6 months.

[c] SD of boundary and background exposure is the SD of the mean of the TLD chips at that location.

at points of likely maximum deposition based on stack height, predominant wind direction and average stability class. Soil samples at each selected location were collected by taking five soil cores or plugs, 10 cm in diameter and 5 cm in depth from a square meter area. The five samples were then combined into a single, composited, pulverized sample and plutonium, strontium, and gamma spectrometry analyses were performed on the < 0.5 mm fraction.

Results from boundary and onsite samples were compared to samples from the background areas of Blackfoot, Minidoka, and Pocatello (table 5). Only the gamma-emitting isotopes which were consistently above the minimum detection limits were included in this report. Generally, results from the background samples were similar to those collected near the NRTS boundary. Average cesium-137 and strontium-90 levels near the ICPP and ARA areas were a factor of 4 to 8 higher than background. Although the number of samples was limited, it appeared that strontium-90 levels at locations sampled onsite and on the boundary were higher than background samples. These slightly larger averages, if real, are probably the result of past atmospheric releases from the Idaho Chemical Processing Plant.

Plutonium-239 levels (average of 0.061 pCi/g) near the Radioactive Storage Area were slightly higher than concentrations in other areas. The highest plutonium-239 concentration (0.09 pCi/g) occurred in a boundary sample south southeast of EBR-II. A Radioecology Program study has begun to further define

Table 5. Results of onsite, boundary, and background soil monitoring at the National Reactor Testing Station January-December 1971

Location	Number of samples	Plutonium-239 (pCi/g dry weight)		Plutonium-238 (pCi/g dry weight)		Strontium-90 (pCi/g dry weight)		Cesium-137 (pCi/g dry weight)		Cerium-praseodymium-144 (pCi/g dry weight)	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
ICPP	6 [a]5	0.036	0.026 ± 0.01	0.059	0.025 ± 0.018	27.0	7.0 ± 10.0	24	8.0 ± 8.6	.9	[b]0.5 ± 0.6
RSA	4 4	.077	.061 ± .018	.005	.005 ± .00	NA	NA	1.2	1.0 ± 2.4	.9	.6 ± .02
BORAX	1 2	.04	.04	NA	NA	NA	NA	1.5	.8	.7	.4 ± .5
TREAT, EBR-II	6 6	.024	.013 ± .006	.006	.004 ± .00	0.80	0.56 ± .21	2.0	.8 ± .6	.5	.4 ± .1
SPERT	2 6	.022	.015 ± .009	.005	.005 ± .00	NA	NA	1.0	.6 ± .02	.5	.2 ± .4
ARA	4 7	.024	.020 ± .006	.004	.002 ± .00	8.8	3.0 ± 3.5	21.0	4.7 ± 7.4	.7	.2 ± .4
TSF	1 2	.021	.021	<.001	<.001	NA	NA	.7	.6	.3	.2 ± .3
IET	1 2	.009	.009	<.005	<.005	.6	.6	.6	.4	.2	.1 ± .2
EBR-I	2 2	.035	.022 ± .018	.001	.001 ± .00	NA	NA	1.0	.8 ± .4	.5	.2 ± .4
NRF	0 2	NA	NA	NA	NA	NA	NA	.9	.7 ± .3	.5	.2 ± .4
TRA	0 2	NA	NA	NA	NA	NA	NA	.8	.8 ± .7	.0	.6 ± .6
Boundary [c]	10 10	.09	.031 ± .025	.006	.003 ± .002	1.31	.66 ± .35	1.6	.92 ± .47	.9	.5 ± .2
Background	4 4	.067	.031 ± .025	.009	.005 ± .004	.35	.09 ± .3	2.6	1.4 ± .09	.53	.32 ± .15

[a] Samples for gamma spectrometry.

[b] Indicates range of average, ± indicates standard deviation.

[c] See figure 5 for background and boundary sample locations.

NA, no analysis.

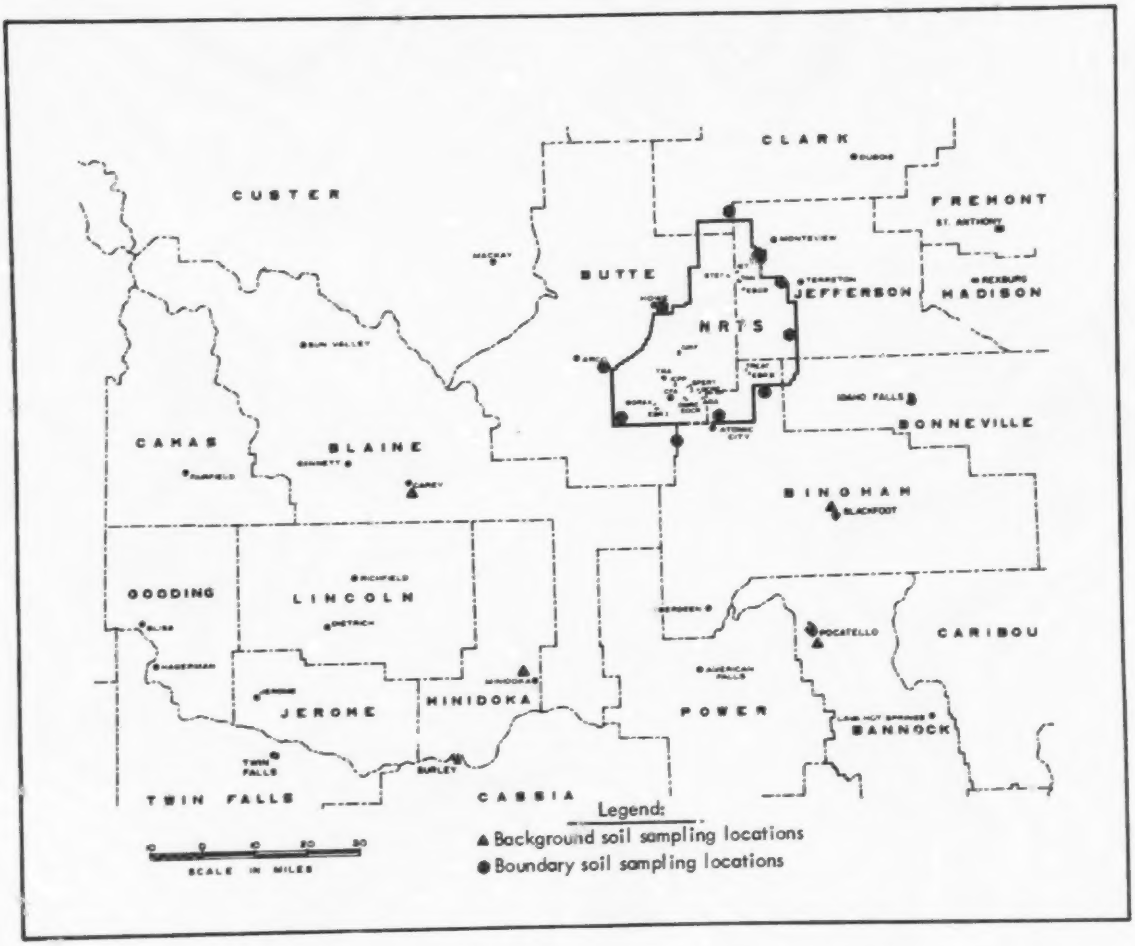
CLARK
DUBOIS
CUSTER
FREMONT
ST. ANTHONY
MACKAY
MONTEVIEW
BUTTE
TERRETON
JEFFERSON
REXBURG
MADISON
HOWE
NRTS
SUN VALLEY
ARCO
IDAHO FALLS
ATOMIC CITY
BONNEVILLE
CAMAS
BLAINE
GANNETT
FAIRFIELD
CAREY
BINGHAM
BLACKFOOT
RICHFIELD
GOODING
LINCOLN
DIETRICH
BLISS
ABERDEEN
POCATELLO
CARIBOU
HAGERMAN
AMERICAN FALLS
MINIDOKA
JEROME
POWER
LAVA HOT SPRINGS
BANNOCK
TWIN FALLS
BURLEY
TWIN FALLS
CASSIA
SCALE IN MILES
Legend:
▲ Background soil sampling locations
● Boundary soil sampling locations

Figure 5. Locations of NRTS boundary and background soil samples

and document levels of transuranic, gamma-emitting nuclides and strontium-90 in the ecosystem near the Radioactive Storage Area. When the study is completed, data will be published in a separate paper.

The average plutonium-238 level of 0.025 pCi/g near the ICPP appeared to be slightly higher than samples from other locations. Plans have been formulated to collect additional samples in FY-1974 near and downwind of the Idaho Chemical Processing Plant. These additional samples will supply the necessary data to permit a realistic evaluation of soil contamination levels resulting from ICPP operations.

In the future, the soil monitoring program at the NRTS will provide for more detailed sampling in certain areas as well as periodic resampling of larger areas in order to monitor any possible increased activity in the soil.

Water monitoring program

Although the NRTS receives an average of approximately 20 cm (8 inches) of precipitation per year, underlying the desert plain is the large Snake River Plain aquifer. The lateral flow of this water, the major aquifer of Idaho, is about 3.75 × 10^9 liters (10^9 gallons) per day. The aquifer recharge to the NRTS area origi-

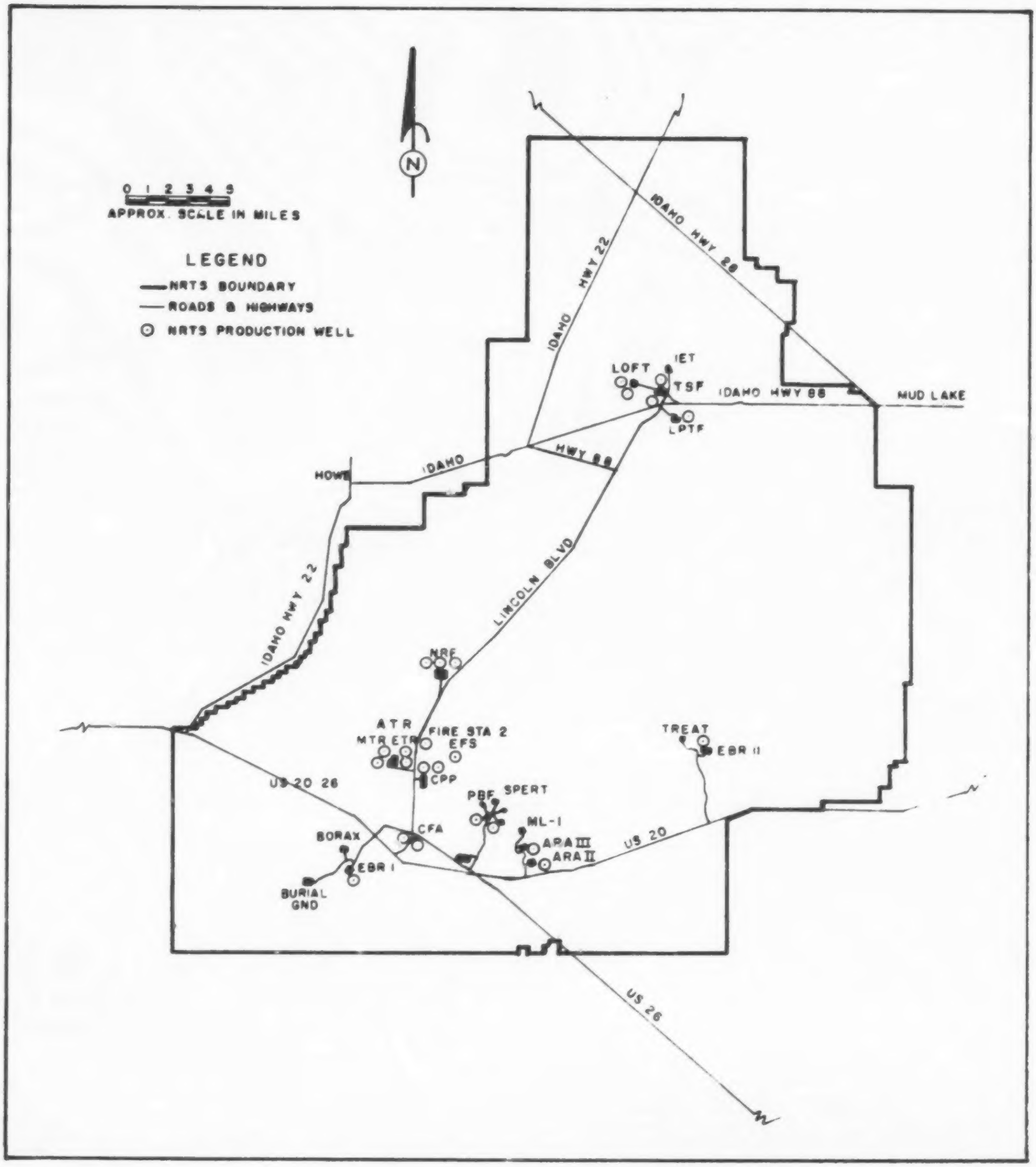
N
0 1 2 3 4 5
APPROX. SCALE IN MILES
LEGEND
NRTS BOUNDARY
ROADS & HIGHWAYS
NRTS PRODUCTION WELL
IDAHO HWY 28
IDAHO HWY 22
IDAHO HWY 88
MUD LAKE
LOFT
IET
TSF
LPTF
HOWE
IDAHO HWY 88
LINCOLN BLVD
NRF
ATR
MTR
ETR
FIRE STA 2
EFS
CPP
US 20 26
PBF
SPERT
ML-1
ARA III
ARA II
US 20
TREAT
EBR II
CFA
BORAX
EBR I
BURIAL GND
US 26

Figure 6. Location of NRTS drinking water production wells

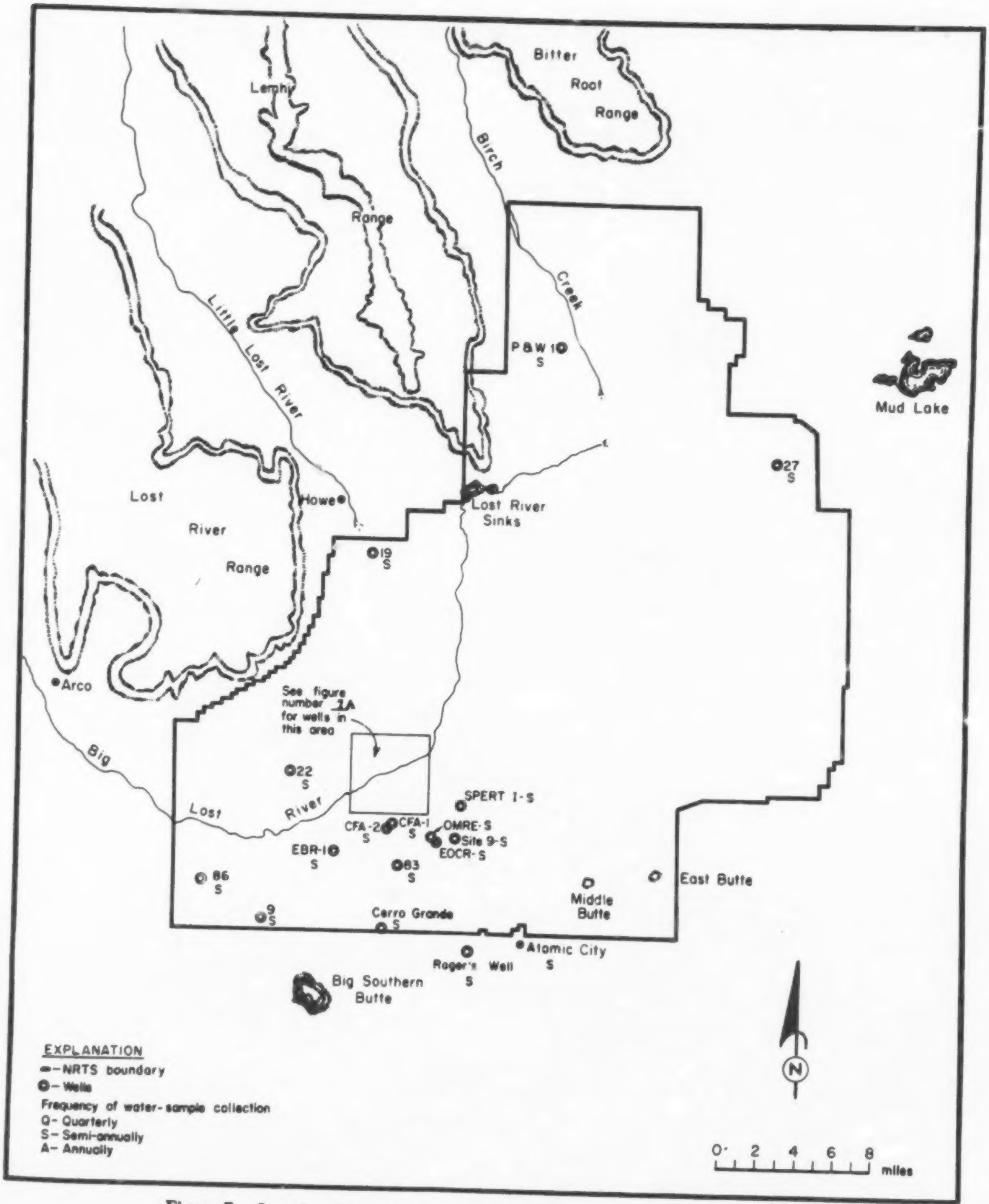
Bitter Root Range
Lemhi Range
Birch Creek
Little Lost River
Lost River Range
Howe
Lost River Sinks
P&W 1 S
27 S
Mud Lake
19 S
Arco
See figure number 7A for wells in this area
Big Lost River
22 S
SPERT I-S
CFA-2 S
CFA-1 S
OMRE-S
Site 9-S
EOCR-S
EBR-I S
83 S
86 S
9 S
Cerro Grande S
Middle Butte
East Butte
Atomic City S
Roger's Well S
Big Southern Butte
EXPLANATION
— NRTS boundary
⊙ – Wells
Frequency of water-sample collection
Q– Quarterly
S– Semi-annually
A– Annually
N
0 2 4 6 8 miles

Figure 7. Location of monitoring wells on the NRTS and frequency of sample collection by the U.S. Geological Survey

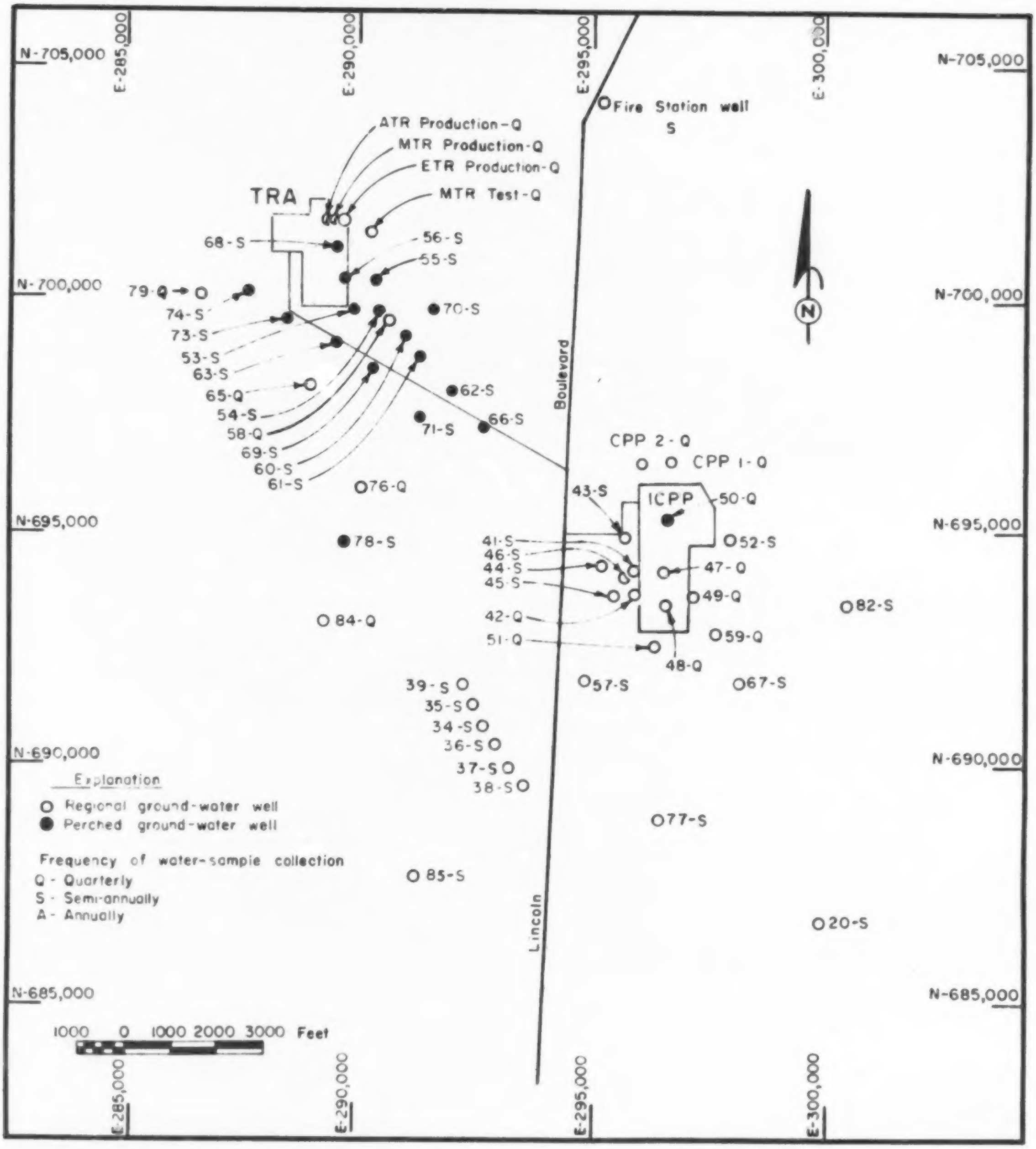
N-705,000
E-285,000
E-290,000
E-295,000
E-300,000
Fire Station well
S
ATR Production-Q
MTR Production-Q
ETR Production-Q
MTR Test-Q
TRA
68-S
56-S
55-S
N-700,000
79-Q
74-S
73-S
53-S
63-S
65-Q
54-S
58-Q
69-S
60-S
61-S
70-S
62-S
66-S
71-S
76-Q
Boulevard
CPP 2-Q
CPP 1-Q
ICPP
43-S
50-Q
N-695,000
78-S
41-S
46-S
44-S
45-S
42-Q
51-Q
52-S
47-Q
49-Q
59-Q
48-Q
82-S
84-Q
39-S
35-S
34-S
36-S
37-S
38-S
57-S
67-S
N-690,000
77-S
Explanation
○ Regional ground-water well
● Perched ground-water well
Frequency of water-sample collection
Q - Quarterly
S - Semi-annually
A - Annually
85-S
20-S
Lincoln
N-685,000
1000 0 1000 2000 3000 Feet
N

Figure 8. Location of monitoring wells near the ICRP and TRA and frequency of sample collection by the U.S. Geological Survey

82

nates primarily as underflow from the northeastern part of the Snake River Plain and also north, northeast, and northwest of the station. Addtional water comes from the Big and Little Lost Rivers and Birch Creek which sink into the porous soils in the NRTS area. These waters move slowly south or southwest through the aquifer and discharge at numerous springs along the Snake River between Milner and Bliss, Idaho. Aquifer water of the Snake River Plain is used for irrigation of crops and domestic purposes. NRTS facilities obtain water from this aquifer and some discharge low level liquid radioactive waste into the aquifer. Other radioactive waste water is discharged into shallow ponds and slowly percolates downward. Because of this discharge of wastes, the water sampling program monitors radioactivity levels through periodic sampling of drinking water production wells, special monitoring wells and the Snake River.

Water samples from NRTS drinking water production wells (figure 6) normally are collected every 3 weeks, while offsite production wells and surface waters (figure 4) are sampled semiannually by the HSL. Gross alpha, gross beta, and tritium activities are measured routinely on all samples and, in addition, strontium-90 analyses are performed on the ICPP drinking water samples.

In addition to the Health Services Laboratory's sampling of production wells, the U.S. Geological Survey periodically samples a number of monitoring wells of the NRTS (figures 7 and 8). The majority of these wells are located near the ICPP, where low level radioactive waste water is returned to the aquifer, and near TRA, where waste disposal ponds are utilized. Some of these wells monitor the regional aquifer while others monitor water which has percolated downward but remains perched above the regional aquifer. One well monitors a zone of perched water near the ICPP. Tritium concentrations are determined for all samples. Strontium-90 concentrations are measured for samples from selected wells.

The drilling of four additional monitoring wells near the Radioactive Storage Area was completed in FY-1973 and sampling initiated. Samples from these wells are being collected on a monthly basis during FY-1974.

All the samples (table 6) from the drinking water wells were below the minimum detectable concentration for gross alpha activity, and some of the samples from the ICPP were the only ones indicating gross beta levels above the minimum detection level. The maximum gross beta concentration detected in the ICPP area samples was 20 pCi/liter. This value is below the guide value of 30 pCi/liter for unidentified

Table 6. Results of drinking water and surface water sampling in the vicinity of the National Reactor Testing Station during FY 1973

Location	Number of wells	Samples collected	Gross alpha[a] (pCi/liter)		Gross beta[b] (pCi/liter)		Tritium[c] (nCi/liter)		Strontium-90[d] (pCi/liter)	
			Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Onsite:										
EBR-I	1	1	BDL	BDL	BDL	BDL	BDL	BDL		
CFA	2	26	BDL	BDL	BDL	BDL	90	59		
TRA	3	104	BDL	BDL	BDL	BDL	BDL	BDL		
ICPP	2	28	BDL	BDL	20.	[e]1.4–5.9	6.0	[e]2.8–3.1	7.0	[f]3.0
NRF	3	36	BDL	BDL	BDL	BDL	BDL	BDL		
TAN	5	126	BDL	BDL	BDL	BDL	BDL	BDL		
SPERT-PBF	2	26	BDL	BDL	BDL	BDL	BDL	BDL		
ARA	2	52	BDL	BDL	BDL	BDL	BDL	BDL		
EFS	1	1	BDL	BDL	BDL	BDL	BDL	BDL		
EBR-II	1	26	BDL	BDL	BDL	BDL	BDL	BDL		
Fire Station #2	1	26	BDL	BDL	BDL	BDL	BDL	BDL		
Offsite:										
12 locations (see figure 4)	12	24	BDL	BDL	BDL	BDL	BDL	BDL		
Snake River[g]	2	4	BDL	BDL	BDL	BDL	BDL	BDL		

[a] AEC guide for gross alpha in drinking water is 30 pCi/liter for an individual in an uncontrolled area. Detection limit for gross alpha concentration is 3 pCi/liter.

[b] AEC guide for gross beta in drinking water is 30 pCi/liter for an individual in an uncontrolled area. Detection limit for gross beta concentration is 5 pCi/liter.

[c] AEC guide for tritium in drinking water is 3 μCi/liter for an individual in an uncontrolled area. Detection limit for tritium is 2 nCi/liter.

[d] AEC guide for strontium-90 in drinking water is 300 pCi/liter for an individual in an uncontrolled area.

[e] The upper limit is calculated considering BDL at the detection level; for lower figure, BDL is considered as 0.

[f] 80 samples from ICPP were analyzed for strontium-90.

[g] Surface water samples.

BDL, below detectable levels.

beta emitters in drinking water (*1*). Levels of tritium above the detection limit were found in the ICPP and CFA area drinking water wells. The maximum tritium concentration in any single sample, 90 nCi/liter, is well below the guide value of 3 μCi/liter (*1*). The tritium detected in CFA water is a result of tritium released to the aquifer in the ICPP and TRA areas. The highest strontium-90 concentration in any one production well sample from the ICPP area was 7.0 pCi/liter. The strontium-90 concentration is less than 2.4 percent of the AEC guide value for strontium-90 in drinking water.

Results of the USGS samples from the regional and perched groundwater monitoring wells (table 7) in both the TRA and ICPP areas indicate that all tritium analyses were below the guide values for drinking water consumed by an individual in an uncontrolled area. The highest tritium concentration in a single sample from the regional aquifer was 199 nCi/liter or less than 7 percent of the drinking water value of 3 μCi/liter for an individual in an uncontrolled area. Two wells in the CFA area were the only other wells either on- or offsite where tritium concentrations were detected. As pointed out above, the tritium concentrations at CFA result from releases to the aquifer at the ICPP and TRA areas.

The highest sample analysis for strontium-90 from USGS wells monitoring the regional aquifer at ICPP was 220 pCi/liter which is about ¾ of the guide value of 300 pCi/liter for drinking water for an individual in an uncontrolled area. The average strontium-90 concentration in the regional aquifer, 40 pCi/liter, at ICPP was less than 15 percent of the guide value. Further evidence of the low levels of radioactive waste entering the regional aquifer is demonstrated by the perched groundwater data. The average strontium-90 concentrations in the perched aquifer both at TRA and ICPP were less than three times the drinking water guide values for an individual in an uncontrolled area. Even the maximum concentration recorded for a single sample from the perched aquifer was only four times the above guide values. These higher concentrations were observed in shallow wells monitoring perched water close to the liquid waste pond near TRA and near the disposal well at ICPP; these waters are neither accessible for use as drinking water nor in an area which is open to the public.

Food monitoring

The food monitoring program supplies information on amounts of radioactivity in food collected in the NRTS vicinity. Comparisons between levels of activity in food products collected near the NRTS boundary and similar samples collected in background areas provide a method for evaluating any increases of radioactivity in food as a result of NRTS operations.

Each week a composite Grade A milk sample is collected from areas north and south of Idaho Falls. Monthly samples of Grade B milk are collected from dairies and an individual farm

Table 7. Results of monitoring well sampling by the U.S. Geological Survey at the National Reactor Testing Station during FY 1973

Location	Number of wells	Groundwater type	Number of samples		Tritium [a] (nCi/liter)		Strontium-90 [b] (pCi/liter)	
			^{3}H	^{90}Sr	Maximum	Average	Maximum	Average
TRA	8	Regional	38	—	173	[c] 19–20	NA	NA
TRA	15	Perched	42	18	614	197	1 170	160
ICPP	28	Regional	69	47	199	50	220	40
ICPP	1	Perched	4	4	220	208	820	780
Other onsite	15	Regional	42	—	84	[c] 11–13	NA	NA
Offsite	2	Regional	3	—	2	[c] 0– 2	NA	NA

[a] AEC guide value (*1*) for drinking water is 3 μCi/liter for an individual in an uncontrolled area. These samples are from special monitoring wells which are not utilized for drinking water. Detection limit is 2 nCi/liter.

[b] AEC guide value (*1*) for drinking water is 300 pCi/liter for an individual in an uncontrolled area.

[c] The upper limit is calculated considering BDL at the detection level; for lower figure, BDL is considered as 0.

NA, no analysis.

in rural areas near the NRTS (figure 4). All milk samples are analyzed for cesium-137 and iodine-131 by gamma spectrometry and, semi-annually, the samples are analyed for strontium-90.

During FY-1973, all milk samples were below the minimum detection limit (MDL) for cesium-137 and iodine-131. The MDL for cesium-137 in milk is 30 pCi/liter and for iodine-131 in milk, the MDL is 20 pCi/liter. Strontium-90 concentrations (table 8) were less than 1 percent of the guide (*4*) and are believed to be the result of worldwide fallout.

Table 8. Strontium-90 concentrations in milk samples collected near the National Reactor Testing Station, FY 1973

Location	Strontium-90 (pCi/liter)	
	Maximum	Average
Background:		
Idaho Falls [a]	3.0	3.0
Minidoka	3.0	3.0
Dietrich	3.0	[c] 1.5–2.5
Carey	4.0	2.0–3.0
Firth & New Sweden (near Idaho Falls)	3.0	1.5–2.5
Lake & Riverside (Tabor, Blackfoot, Aberdeen areas)	4.0	2.0–3.0
Boundary:		
Mud Lake	6.0	5.2
Reno Ranch	3.0	1.5–2.5
Howe	[b] BDL	BDL
Arco	BDL	BDL

[a] Only two samples from each location were analyzed during the year for strontium-90.

[b] BDL = below detection limits. The MDL for strontium-90 in milk is 2 pCi/liter.

[c] The upper limit is calculated considering BDL at detection level, lower figure is considering BDL as 0.

During the fall, wheat samples consisting of both seed and hulls from farms and elevators near the NRTS boundary and at greater distances (figure 4) are analyzed for strontium-90. In addition, the wheat sample from Monteview, a boundary community, was analyzed by gamma spectrometry. No gamma-emitting isotopes other than those which occur naturally were detected. Strontium-90 activity levels (table 9) in wheat close to the site boundaries were similar to determinations in samples at greater distances. These levels are believed to be the result of worldwide fallout and not due to NRTS activities.

Table 9. Strontium-90 in wheat samples near the NRTS during fall 1972

Sampling location	Strontium-90 concentration (pCi/kg)
Arco	[a] 11 ±2
Monteview	25 ±2
Minidoka	21 ±2
Dietrich	22 ±2
Carey	16 ±7
Idaho Falls	22 ±2
Blackfoot	10 ±2
American Falls	13 ±2

[a] Standard deviation from counting statistics.

Antelope (*Antilocapra americana*) are present on and near the NRTS during most of the year. Since the area around the NRTS is open to hunting and antelope are consumed by sportsmen, these animals represent a potential source of radionuclide intake by man. Various antelope tissues are sensitive bioindicators of levels of certain radionuclides in the environment and thereby provide knowledge concerning the ultimate fate of radionuclides released to the atmosphere. Therefore, a study was designed as part of the radioecology program whereby antelope routinely are collected on a monthly basis on and near the NRTS. Additional samples from road accidents and sportsmen-donated samples also are utilized.

The thyroid, muscle, lungs, liver, and rumen samples collected are analyzed by gamma spectrometry. Additional analysis for strontium-90 levels in bone and analyses of bone and lung samples for transuranic nuclides are planned. In this report, the levels in edible (liver and muscle) parts of the animals are presented (table 10).

With one exception, cesium-137, cesium-134, and cobalt-60 were the only isotopes detected in liver and muscle tissues. Cobalt-60 was present in only a few samples and when present was slightly above the minimum detection limit. Cesium-134 was detectable only in onsite samples collected near the ICPP. Cesium-137 levels in muscle and liver samples from animals collected onsite were significantly higher ($\alpha = 0.05$) than those collected offsite. The highest cesium-137 levels detected were 1130 pCi/kg muscle and 1770 pCi/kg liver. These samples, as well as others collected near the ICPP, were higher than samples from other locations. Offsite samples had cesium-137 levels of 22–60 pCi/kg of muscle and 31–80 pCi/kg of liver.

Table 10. Gamma emitting isotopes present in muscle and liver samples from antelope on and near the National Teactor Testing Station

Antelope collection number	Date	Distance and direction from ICPP (km)	Muscle			Liver		
			^{137}Cs[a] (pCi/kg wet weight)	^{134}Cs[a] (pCi/kg wet weight)	^{60}Co[a] (pCi/kg wet weight)	^{137}Cs[a] (pCi/kg wet weight)	^{134}Cs[a] (pCi/kg wet weight)	^{60}Co[a] (pCi/kg wet weight)
Offsite:								
72-1	9-23-72	84 NNW	38	[a] BDL	16	50	BDL	BDL
72-2	9-24-72	93 NNW	54	BDL	19	46	BDL	BDL
72-3	9-24-72	88 NNE	46	BDL	BDL	NA	NA	NA
72-4	9-24-72	74 NE	40	BDL	40	80	BDL	BDL
72-5	9-24-72	88 NE	60	BDL	60	50	BDL	BDL
73-1	1-12-73	90 NE	22	BDL	BDL	NA	NA	NA
73-2 [b]	2- 9-73	37 NW	53	BDL	BDL	73	BDL	BDL
73-5	5-11-73	85 NW	BDL	BDL	BDL	31	BDL	BDL
Onsite:								
72-7	10- 8-72	31 NNE	130	BDL	32	100	BDL	60
72-8	10-16-72	.4 N	920	BDL	BDL	1430	71	BDL
72-9	11- 6-72	.4 S	1130	100	BDL	1770	120	BDL
72-10	11- 9-72	6 SW	680	BDL	BDL	1740	150	BDL
72-11	11- 9-72	6 SW	680	18	BDL	1670	120	BDL
72-12	12-19-72	47 NNE	29	BDL	BDL	46	BDL	BDL
73-3	3- 9-73	6 SE	29	BDL	BDL	60	BDL	BDL
73-4	4-20-73	2 E	240	11	BDL	870	60	BDL
73-6	6-22-73	3 SW	430	BDL	BDL	64	BDL	BDL

[a] Detection limits were: 10 pCi/kg for ceisum-134 and 10 to 40 pCi/kg for cobalt-60. Detection limit for cesium-137 was 20 pCi/kg except for 73-5 muscle which was 200 pCi/kg.

[b] The liver sample from this animal contained 10 pCi/kg of manganese-54.

BDL, below detectable level.

NA, no analysis.

From the data collected during FY-1973, it appears that the cesium levels in the tissues of the animals collected offsite were the result of worldwide fallout with possible small contributions from NRTS activities. More samples at various locations near the boundary and offsite are needed. Also, samples have not been collected during a major waste solidification operation at ICPP. Therefore, a detailed analysis of the data with respect to distance and direction from ICPP cannot be attempted. Additional samples will be collected during the next 2 years. When sufficient data are available, the results will be reported in a future publication. However, the antelope on the NRTS probably do not contribute significantly to the radionuclide intake of sportsmen since the NRTS is closed to hunting. If the animals leave the NRTS, the cesium levels in their bodies would rapidly come into equilibrium with their new environment, since the biological half-time of cesium in antelope probably is similar to the 14-day period observed in other wild ruminant species (*5*). Further, the fall antelope migration across the NRTS does not occur until after the hunting season. If a sportsman consumed an entire antelope with the highest level of cesium-137 in muscle and with the highest level of cesium-137 in the liver of the animals collected to date, calculations (*6*) indicate that he would receive a radiation dose of < 2 mrem.

Iodine-129 monitoring

During processing of spent nuclear fuels and calcination of resultant liquid wastes at the Idaho Chemical Processing Plant, small amounts of iodine-129 are present in the atmospheric effluent. The Radioecology Program is attempting to determine the accumulative deposition of iodine-129 in the NRTS and surrounding environs and to establish a monitoring program for current iodine-129 releases.

Beginning in September 1972, thyroids obtained from a monthly antelope collection as well as samples obtained from road-killed antelope have been analyzed for iodine-129 and stable iodine. Iodine-129 levels are determined by activation analysis techniques and iodine-127 levels are determined spectrophotometrically. Thyroids collected after April 1973 will be analyzed at a later date since the ETR, previously used to irradiate samples, is no longer operating on a continuous basis and a new irradiation facility is not yet complete.

Specific activity of iodine-129, the ratio of

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the activity of iodine-129 to the mass of stable iodine (^{127}I), varied from 69 nCi ^{129}I/g iodine in a thyroid sample collected 6 km southwest of ICPP to 0.28 nCi ^{129}I/g iodine in a thyroid sample collected 90 km northeast of ICPP (table 11). All the thyroids collected were above the average background level of 17 ± 14 pCi ^{129}I/g iodine as determined for eight mule deer thyroids from New Mexico and Colorado.[2] The specific activities in the background samples were similar to levels in bovine thyroids in Massachusetts (*7*). The highest specific activity determined was only 5 percent of the limiting specific activity of 1.4 μCi ^{129}I/g iodine (*8*). The limiting specific activity is that specific activity which, if present in a human thyroid, would result in a dose rate of 500 mrem/yr, the dose limit for an individual in an exposed population. However, the data on antelope thyroids is not directly applicable to humans in the NRTS area since the fraction of total iodine intake from local sources for the surrounding population is not known.

Table 11. Specific activity of iodine-129 in antelope thyroids on and near the National Reactor Testing Station

Antelope number	Date of collection	Distance and direction from ICPP (km)	nCi ^{129}I/g iodine
72-7	10- 8-72	31 NNE	[a]2.2
72-8	10-16-72	0.4 N	[a]47
72-10	11- 9-72	6 SW	[a]49
72-11	11- 9-72	6 SW	[a]69
72-12	12-19-72	47 NNE	7.9
73-1	1-12-73	90 NE	.28
73-2	2- 9-73	37 NW	2.4
73-3	8- 9-73	7 SE	2.1
73-4	4-20-73	2 E	9.6

[a] Iodine-127 levels not determined in this sample. An average iodine-127 value of 1120 μg/g tissue determined from other antelope thyroid samples was used in this calculation.

The biological half-life of iodine in antelope thyroids probably is similar to the 33-day half-life of iodine in mule deer thyroids (*9*). Since the antelope collected near the ICPP during October and November were thought to be part of a migrating herd which had been in the area only a short time, it is doubtful that the thyroid iodine-129 levels were in equilibrium with the environment in that area. The antelope (72-12, 73-1, 73-2) collected at more distant locations most likely were as close to ICPP at the time of collection as they had been at any other time in the previous 6 months. Therefore, the iodine-129 levels in these thyroids may be representative of those found in the environment in the area where they were collected and were not due to recent travels nearer the ICPP.

Many more samples from different directions and locations need to be collected before the distribution of iodine-129 in the NRTS and surrounding area can be completely described. However, preliminary data do indicate that effluents from the ICPP during the previous 19 years have increased the iodine-129 levels in the terrestrial ecosystem at the NRTS and surrounding area. The data further demonstrate that the levels still are only a fraction of the limiting specific activity.

Beginning in the fall 1973, antelope thyroids will be collected from cooperating sportsmen in antelope hunting areas surrounding the NRTS and extending into mountain valleys to the north and northeast. In addition, a number of deer thyroids will be obtained from the mountains near the upper Snake River Plain. Analysis of these thyroids should provide the necessary data to determine the amount and extent of iodine-129 deposition in the upper Snake River Plain as well as the mountainous area adjacent to the Plain. More thyroids will be sought from other parts of Idaho and other Rocky Mountain areas remote from the NRTS to improve our estimate of the concentration from weapons testing fallout.

Summary

This report describes the results of the environmental monitoring program conducted by the Health Services Laboratory at the National Reactor Testing Station. The results of the NRTS air monitoring program for FY-1973 indicated that some onsite monitoring stations had increased gross beta air concentrations as a result of NRTS operations. Although NRTS atmospheric releases occasionally were detected at one boundary monitoring station, the NRTS contribution at this location was so minute that it did not significantly alter the gross beta average air concentration.

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[2] Unpublished data, O. D. Markham, C. P. Willis, T. E. Hakonson, and F. W. Whicker.

Calculations show that the maximum 1972 whole body dose to an individual in an offsite population resulting from direct exposure to or inhalation of NRTS radioactive atmospheric effluents (both gaseous and particulates) was 1.5 mrem. The computed exposure to the population (66 918) residing within 80 km (50 miles) of the NRTS during 1972 was 2.4 man-rem.

None of the offsite well water or surface water samples contained any gross alpha, gross beta, or tritium activity above the detection limits for these analyses. The only radioactivity detected in water was from samples collected at onsite locations in the ICPP, TRA, and CFA areas; the observed levels in the aquifer were below the appropriate guide values for drinking water.

Thermoluminescent dosimeters deployed at various onsite, boundary and background locations indicated that NRTS activities did not increase the offsite radiation exposure. At several onsite monitoring locations, the exposures were higher than control monitoring locations as the result of operations of facilities, storage of radioactive waste or radioactivity in evaporation ponds and possibly surface radioactive contamination.

Radioactivity concentrations in soil samples collected near the boundary of the NRTS generally were similar to those collected in background locations; however, it appeared from a limited number of samples that average strontium-90 levels at locations onsite and on the boundary were higher than background averages.

The only fission or activation product detected in milk and wheat was strontium-90, and the levels are believed to result from worldwide fallout from previous nuclear weapons testing and not related to NRTS operations.

Cesium-137, cesium-134, and cobalt-60 were detected in edible portions of antelope. Cesium-134 was detected only in onsite samples collected near the ICPP. Cobalt-60 was present in a few samples and when present was only slightly above the detection limits. Cesium-137 in muscle and liver samples collected from onsite antelope were significantly higher than samples from offsite animals. The highest level of cesium-137 detected in muscle was 1130 pCi/kg and the highest level in liver was 1770 pCi/kg. The potential dose to an individual consuming a whole antelope with the highest tissue concentrations is less than 2 mrem.

Sampling for iodine-129 on and near the NRTS indicates that releases from the ICPP have increased the iodine-129 level in the terrestrial ecosystem at the NRTS and surrounding area. However, the samples analyzed to date indicate that the specific activities of iodine-129 found in the NRTS environment are only a fraction of that which, if present in humans, would give the maximum permissible level for iodine-129.

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Personnel and Environmental Thermoluminescent Dosimetry for a University Reactor Located in a Semitropical Area

P. S. Weng[1] *and C. Y. Huan*[2]

The ^{7}LiF-Teflon discs were added to the film badges for personnel monitoring during a 6-month period. The results showed a consistently higher dose in the thermoluminescent dosimeter than in the photographic film dosimeter, which might exhibit about 90 percent fading during the 4-week period in a hot and humid climate. In winter time, it was found that the response from both LiF-Teflon disc and film showed more consistent results due to better climate conditions in Taiwan. The $CaSO_4$:Dy and $CaSO_4$:Tm phosphor powders and LiF:Mg, Ti, enclosed in a knot of bamboo stick, were used for environmental monitoring at a university reactor site and inside a research reactor building. The results showed that they were unaffected by extremes of humidity and environmental temperatures in area monitoring, either indoors or outdoors.

Since Taiwan is an island located near the tropical zone, it is important to select dosimeters for both personnel and environmental monitoring that are usable under conditions of high temperature and humidity. A photographic film dosimeter had been used for this purpose since 1961. A recent test showed that gamma-irradiated Kodak Personnel Monitoring Film Type 2 stored in the ambient climate exhibited about 60 to 90 percent fading during 4 weeks with little protection provided by additional sealing (*1*). The test was carried out during May and June which are not the hottest and most humid months in Taiwan (temperature varied between 23 and 33°C, relative humidity between 75 and 95 percent).

A personnel radiation exposure obviously can occur at the beginning as well as at the end of the monitoring period. The high fading rate makes the application of any correction factors quite difficult. The same situation occurred for the environmental monitoring. The change from the film badge to the more accurate and stable solid-state dosimeters was necessary.

Personnel dosimetry

The most conservative approach was adopted, i.e., to add TLD detectors to the film badge for several months. The 13 mm diameter × 0.4 mm thick discs of LiF-Teflon of Teledyne Isotopes were used because of the consideration of obtaining maximum sensitivity. The minimum dose, defined as three times the standard deviation of the background, was 15 mrad. The tissue-equivalence of LiF-Teflon dosimeters enables meaningful estimates of dose in x or gamma radiation from a single measurement of a dosimeter for the personnel monitored. The response is independent of photon energy to within 30 percent down to 20 keV. In addition, the LiF-Teflon discs are unaffected by extremes of humidity and environmental temperatures which exist in Taiwan. Readout of LiF-Teflon discs was performed on Teledyne Isotopes model 7100 TLD instrument. Nitrogen was supplied to suppress the spurious thermoluminescence during the readout procedure. The standard deviation of the results was about 3.6 percent.

The LiF-Teflon disc was inserted between the Kodak Personnel Monitoring Film Type 2 (for beta, x, and gamma rays, and Type A (for neutrons) which in turn were inserted into the badge. The description of the Tsing Hua Film

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Badge has been reported elsewhere (*2*). The calibration of the TLD reader was carried out by comparing it with a Victoreen R-meter which measures the drop in potential of a charged capacitor due to an ionization current caused by radiation. A 100 mCi cesium-137 source was used for this calibration. Half a year's tests with personnel of the Radioisotope Section of National Tsing Hua University showed, as expected, a consistently higher dose in the LiF-Teflon disc than in the film. The results are presented in tables 1–6. The primary radiation source was iodine-131.

Table 1. Comparison between LiF-Teflon discs and film badges during 9 July to 6 August 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	25 mR	BG
3	27 mR	BG
4	BG	27 mR
5	12 mR	BG
6	10 mR	BG
7	BG	BG
8	BG	BG
9	BG	BG
10	BG	BG
11	13 mR	BG
12	11 mR	BG
13	BG	BG
14	BG	BG
15	10 mR	BG
16	14 mR	BG
17	13 mR	BG
18	15 mR	BG
19	17 mR	BG
20	16 mR	BG
21	BG	BG
22	25 mR	BG
23	19 mR	BG

Average background (BG) = 10 mR/4 weeks

Table 2. Comparison between LiF-Teflon discs and film badges during 6 August to 3 September 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	111 mR	BG
3	95 mR	85 mR
4	BG	BG
5	31 mR	27 mR
6	75 mR	71 mR
7	BG	BG
8	BG	BG
9	BG	BG
10	BG	BG
11	1960 mR	BG
12	BG	BG
13	BG	BG
14	BG	BG
15	BG	BG
16	BG	BG
17	BG	BG
18	BG	BG
19	BG	18 mR
20	BG	18 mR
21	1 mR	27 mR
22	BG	BG
23	BG	BG

Average background (BG) = 19 mR/4 weeks

Table 3. Comparison between LiF-Teflon discs and film badges during 3 September to 1 October 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	BG	BG
3	76 mR	BG
4	BG	BG
5	6 mR	BG
6	225 mR	48 mR
7	—	—
8	BG	BG
9	21 mR	BG
10	—	—
11	—	—
12	8 mR	BG
13	BG	BG
14	—	—
15	6 mR	BG
16	—	—
17	BG	54 mR
18	—	—
19	BG	BG
20	BG	BG
22	—	—
23	—	—

Average background (BG) = 23 mR/4 weeks

Table 4. Comparison between LiF-Teflon discs and film badges during 1 October to 29 October 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	BG	BG
3	22 mR	BG
4	BG	BG
5	BG	BG
6	145 mR	60 mR
7	66 mR	41 mR
8	BG	BG
9	BG	BG
10	BG	BG
11	BG	BG
12	BG	BG
13	55 mR	54 mR
14	BG	BG
15	BG	BG
16	—	—
17	BG	BG
18	BG	BG
19	4 mR	BG
20	10 mR	BG
21	BG	BG
22	—	—
23	—	—

Average background (BG) = 17 mR/4 weeks

The background reading also is presented for each disc and the average background reading for each monitoring period appears at the bottom of tables 1–6. The reading in milliroentgens for each monitoring disc is the net reading, i.e., the reading with the background subtracted.

Environmental monitoring

Two different types of dosimeters were selected. CaSO$_4$:Dy and CaSO$_4$:Tm. The calcium sulfate phosphors were produced at National Tsing Hua University by the following procedure (*3*).

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Table 5. Comparison between LiF-Teflon discs and film badges during 29 October to 26 November 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	12 mR	BG
3	48 mR	41 mR
4	BG	BG
5	BG	BG
6	65 mR	138 mR
7	11 mR	BG
8	—	—
9	190 mR	129 mR
10	—	—
11	11 mR	BG
12	16 mR	BG
13	—	—
14	14 mR	BG
15	BG	BG
16	—	—
17	BG	BG
18	BG	BG
19	BG	BG
20	25 mR	41 mR
21	BG	BG
22	11 mR	BG
23	191 mR	BG

Average background (BG) = 21 mR/4 weeks

Table 6. Comparison between LiF-Teflon discs and film badges during 26 November to 24 December 1971

Number	Net doses from:	
	^{7}LiF-Teflon TLD	Film badge
1	BG	BG
2	BG	48 mR
3	23 mR	71 mR
4	BG	27 mR
5	13 mR	34 mR
6	41 mR	119 mR
7	BG	48 mR
8	BG	—
9	23 mR	54 mR
10	26 mR	48 mR
11	BG	41 mR
12	BG	BG
13	30 mR	48 mR
14	16 mR	BG
15	14 mR	BG
16	16 mR	BG
17	12 mR	41 mR
18	18 mR	34 mR
19	BG	41 mR
20	29 mR	48 mR
21	31 mR	41 mR
22	52 mR	54 mR
23	32 mR	71 mR
24	28 mR	66 mR

Average background (BG) = 21 mR/4 weeks

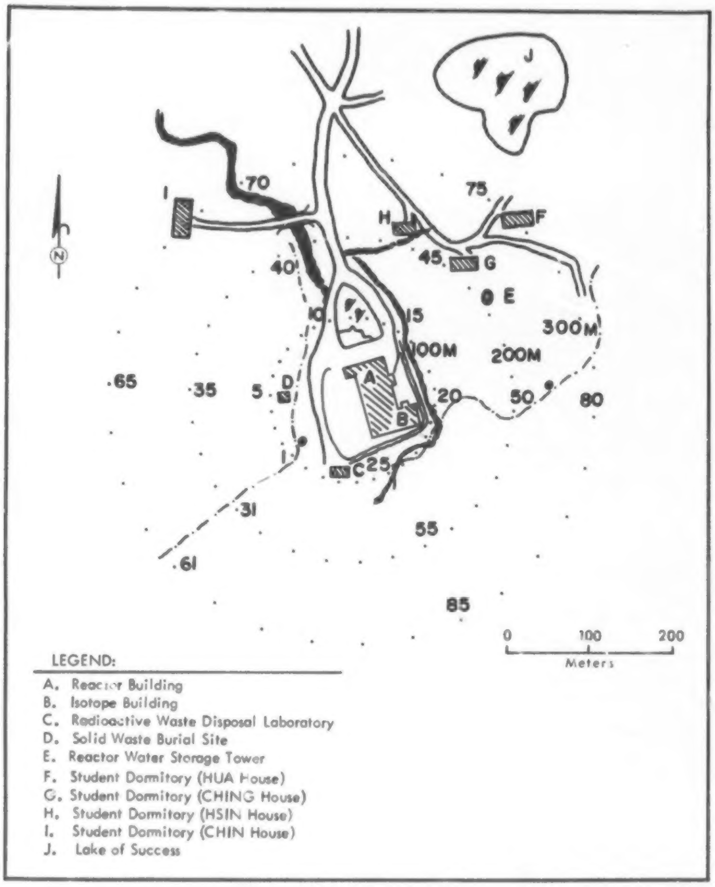
Pure $CaSO_4 \cdot 2H_2O$ was mixed with reagent grade activator material, Dy_2O_3 or Tm_2O_3, to the extent of 0.1 mole percent with regard to $CaSO_4$, and dissolved in concentrated sulfuric acid to form a saturated solution of $CaSO_4$. The solution was then gradually heated up on a hot plate. Agitation was needed frequently to have the calcium sulfate and activator dissolve thoroughly. The temperature then was raised to 300°–320°C to evaporate the sulfuric acid with proper ventilation. Crystals of calcium sulfate doped with dysprosium or thulium were observed to grow with the progress of evaporation of sulfuric acid.

Single crystals, 0.5–2.0 mm long, were obtained after standing for several hours. The temperature then was turned down to about 200°C, and the crystals immediately were transferred into a platinum crucible and placed in an oven for a heat treatment at 700°C for about 5–6 hours in order to thoroughly evaporate any remaining sulfuric acid.

After cooling, the crystals were ground in a mortar into crystalline powder. The crystals were sieved to obtain an 80 to 200 mesh powder. The phosphor which passed through an 80 mesh sieve and stayed in a 200 mesh sieve was retained. The powder thus obtained was readily activated by radiation.

Polyethylene vials containing the phosphor powders, usually good enough for at least two to three readings, first were sealed in polyethylene bags and then wrapped in black paper as a protection against water and light. Bamboo sticks, about 7 cm in diameter and 150 cm long, were used for storing the detectors in a well-protected space about 1 m above the ground. The air had free access to the storage volume above a knot in the bamboo through ventilation holes, and the detectors were protected by a styrofoam layer 4 cm thick and screw-on metal roof carrying warning signs. In addition to $CaSO_4$:Dy and $CaSO_4$:Tm phosphors, LiF:Mg, Ti phosphor was added since it is comparatively energy independent. Ninety monitoring stations have been distributed around the Tsing Hua Open-pool Reactor (THOR, 1 MW(th)) site as shown in figure 1 in an attempt to obtain representative results as shown in tables 7 and 8.

Similar results were obtained from 30 monitoring posts inside a 40-MW research reactor building at a nearby institute (4). The period of area monitoring was from 23 March to 30 May 1973. It showed an indoor background of 0.67 ± 0.03 mR/day, while the outdoor background (in front of the reactor building) was 0.5 ± 0.02 mR/day. The average radiation level in the reactor bay was 9.80 ± 0.43 mR/MW-


J
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40
10
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100M
200M
300M
A
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.35
5
D
20
50
80
B
1
C25
31
55
.61
85
0
100
200
Meters
LEGEND:
A. Reactor Building
B. Isotope Building
C. Radioactive Waste Disposal Laboratory
D. Solid Waste Burial Site
E. Reactor Water Storage Tower
F. Student Dormitory (HUA House)
G. Student Dormitory (CHING House)
H. Student Dormitory (HSIN House)
I. Student Dormitory (CHIN House)
J. Lake of Success

Figure 1. TLD monitoring stations of Tsing Hua open-pool reactor site

day or 2.90 ± 0.13 mR/day as monitored by $CaSO_4$:Dy and $CaSO_4$:Tm powders.

Discussion

Though during the half a year monitoring period the LiF-Teflon discs showed a consistently higher dose than the film, a few exceptions did appear in tables 1 through 6. This was attributed to the location of the LiF-Teflon disc in the badge. The disc was supposed to be placed in the open-window area of the badge between the gamma and neutron track film. However, while being used, a few of the discs had shifted their position to the metal filter portion of the badge.

It is noted that in winter time the readings from both LiF-Teflon disc and film showed more consistent results as shown in tables 5 and 6 due to lower temperature and humidity.

In tables 7 and 8, only the results of monitoring are shown. In fact, the good agreement among the readings of the three different TLD detectors at the same station should be noted. Due to the low sensitivity of LiF, its readings are somewhat less reliable than the $CaSO_4$:Dy

Table 7. Results of half a year background gamma monitoring at THOR site from 22 June to 22 November 1972

Number	Average exposure (mR/6 months)	Number	Average exposure (mR/6 months)	Number	Average exposure (mR/6 months)
1	64.3 ± 4.29	31	65.8 ± 3.88	61	54.6 ± 1.31
2	61.4 ± .42	32	63.8 ± 2.52	62	—
3	61.2 ± 1.16	33	58.0 ± 1.72	63	62.8 ± .57
4	61.9 ± 3.95	34	60.5 ± 2.08	64	68.2 ± 1.65
5	50.5 ± 1.05	35	—	65	64.6 ± .87
6	59.2 ± 2.65	36	63.9 ± 9.25	66	56.8 ± 3.78
7	63.4 ± 3.76	37	57.1 ± 1.80	67	55.6 ± 1.00
8	67.3 ± 1.93	38	61.4 ± .96	68	59.2 ± 1.80
9	59.0 ± 2.96	39	61.2 ± 2.36	69	59.3 ± 3.11
10	55.3 ± 2.31	40	—	70	62.5 ± 2.52
11	61.9 ± 2.44	41	59.9 ± 1.00	71	60.4 ± 1.74
12	60.6 ± 2.02	42	68.2 ± 2.48	72	57.5 ± 1.61
13	60.2 ± 3.00	43	60.9 ± .93	73	59.8 ± 2.37
14	51.1 ± 9.01	44	68.5 ± 6.33	74	53.6 ± 3.50
15	—	45	72.2 ± 3.59	75	56.1 ± 1.06
16	60.0 ± 1.04	46	60.2 ± 3.82	76	58.3 ± 1.36
17	65.2 ± 6.87	47	62.3 ± 2.19	77	60.9 ± 2.81
18	66.3 ± 4.48	48	62.9 ± 2.49	78	66.0 ± 1.48
19	66.4 ± 7.15	49	60.9 ± .56	79	62.1 ± 1.27
20	76.0 ± 8.80	50	63.0 ± 5.99	80	58.1 ± 3.48
21	71.9 ± 6.21	51	61.8 ± 2.43	81	58.3 ± 1.47
22	62.8 ± 2.60	52	59.4 ± 1.99	82	67.7 ± 1.89
23	70.5 ± 2.08	53	60.9 ± 2.59	83	58.2 ± 2.17
24	72.7 ± 6.20	54	—	84	52.9 ± 2.55
25	81.4 ± 6.78	55	53.7 ± 2.55	85	57.1 ± 2.47
26	1120.5 ± 43.70	56	60.2 ± 5.13	86	53.4 ± .67
27	84.8 ± 3.20	57	—	87	—
28	62.0 ± 6.77	58	—	88	56.0 ± 1.48
29	67.6 ± 7.39	59	70.3 ± 4.87	89	57.5 ± 1.55
30	64.2 ± 1.86	60	57.4 ± 1.61	90	53.2 ± 1.7

Table 8. Results of one year background gamma monitoring at THOR site from 26 November 1972 to 26 November 1973

Number	Average exposure (mR/yr)	Number	Average exposure (mR/yr)	Number	Average exposure (mR/yr)
1	256 ±5.3	26	250 ±2.7	64	241 ±3.0
5	243 ±2.8	27	228 ±2.7	65	237 ± .6
6	240 ±2.1	28	225 ±3.1	68	230 ±1.4
8	236 ±2.9	29	225 ±3.8	70	236 ± .5
11	250 ±2.9	30	230 ±2.4	71	232 ±1.1
13	266 ±4.6	32	265 ±4.0	74	220 ±2.9
14	250 ±1.6	36	273 ±4.0	75	217 ±3.5
20	269 ±1.7	37	250 ±2.2	77	224 ±3.6
22	254 ±3.0	38	298 ±4.8	78	236 ±1.7
23	259 ±2.0	48	251 ±1.9	79	230 ±3.4
24	251 ±2.5	49	246 ±5.1	81	237 ±2.4
25	243 ±3.3	63	234 ±2.3	82	284 ± .7

and $CaSO_4$:Tm results. However, the good agreement between the results of LiF, with its fairly photon energy-independent response characteristics and the other highly-dependent response characteristics indicated a low (if any) contribution of low energy photons to the total dose under the conditions of measurement. Though the soft x-ray component has been reported in environmental monitoring, it has probably been absorbed in the bamboo and the packaging of the detectors. Energy dependent detectors $CaSO_4$:Dy and $CaSO_4$:Tm can, therefore, be used in environmental monitoring without the need of energy compensation filters under hot and humid climate conditions.

The monitoring results for 1973 showed much higher doses as compared with the later half of 1972. This was attributed to the nuclear weapons testing at Lop Nor of mainland China and possibly, the French testing at Mururoa Atoll in the South Pacific. All results are expressed with 1-standard deviation. The highest dose 1120.5 ± 43.70 mR (6 months) appearing in monitoring post No. 26 as shown in table 7 was due to the accidental spread of short-lived radioactive wastes. The monitoring results in 1972 showed an average dose ranging from above 100 to 150 mR/yr except for the contaminated area indicated above, and were consistent with data presented by other countries, e.g., 144 mR/yr in the United States (*5*).

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, December 1973

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations; 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports.* Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

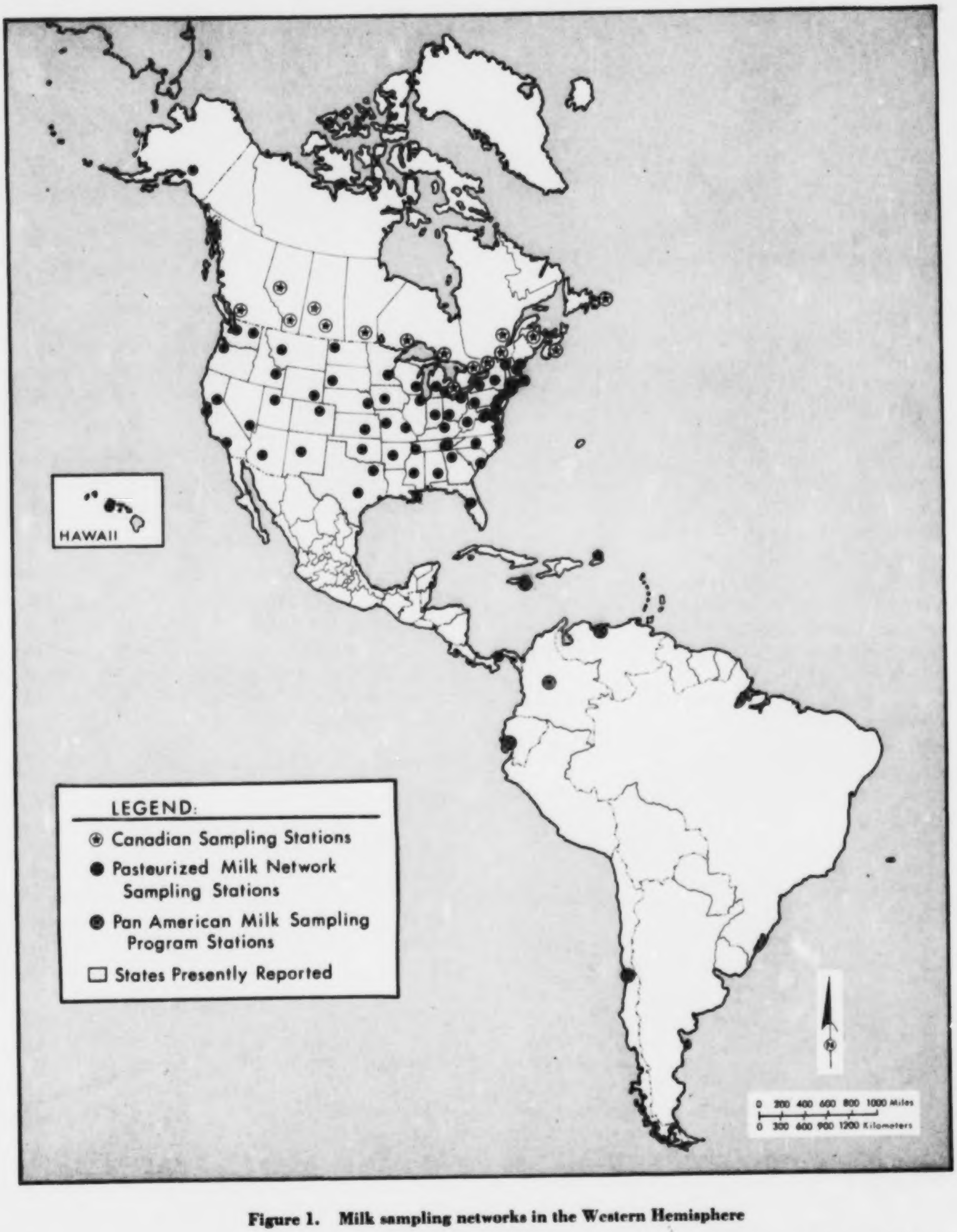
HAWAII
LEGEND:
Canadian Sampling Stations
Pasteurized Milk Network Sampling Stations
Pan American Milk Sampling Program Stations
States Presently Reported
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers
N

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (*2*), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Research and Development conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The fre-

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
Cesium-137:	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
Strontium-89:	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
Strontium-90:	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

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quency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≧50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≧20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≧100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of

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Table 2. Concentrations of radionuclides in milk for December 1973 and 12-month period, January 1973 through December 1973

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter) Strontium-90 Monthly average [b]	Strontium-90 12-month average	Cesium-137 Monthly average [b]	Cesium-137 12-month average
UNITED STATES:						
Ala:	Montgomery [c]	P	NA	5	0	8
Alaska:	Palmer [c]	P	NA	4	0	1
Ariz:	Phoenix [c]	P	NA	0	0	0
Ark:	Little Rock [c]	P	NA	10	0	1
Calif:	Los Angeles [c]	P	NA	0	0	0
	Sacramento [c]	P	NA	1	0	0
	San Francisco [c]	P	NA	0	0	0
	Del Norte	P	13	10	0	6
	Fresno	P	0	1	0	1
	Humboldt	P	3	2	0	1
	Los Angeles	P	0	1	0	2
	Mendocino	P	2	2	0	2
	Sacramento	P	2	2	0	3
	San Diego	P	2	1	0	2
	Santa Clara	P	0	2	0	3
	Shasta	P	2	2	0	2
	Sonoma	P	0	2	0	3
Colo:	Denver [c]	P	NA	3	0	0
	East	R	NS	NA	NS	22
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	2
	South Central	R	NS	NA	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NA	NA	[d] 0	2
	West	R	NS	NA	NS	0
Conn:	Hartford [c]	P	NA	4	2	
	Central	P	NA		NA	
Del:	Wilmington [c]	P	NA	5	0	2
D.C:	Washington [c]	P	NA	3	0	1
Fla:	Tampa [c]	P	NA	4	21	27
	Central	R	4	5	18	27
	North	R	6	6	16	4
	Northeast	R	6	6	28	29
	Southeast	R	6	5	38	48
	Tampa Bay area	P	4	5	31	28
	West	R	9	8	13	9
Ga:	Atlanta [c]	P	NS	4	NS	5
Hawaii:	Honolulu [c]	P	NA	0	0	0
Idaho:	Idaho Falls [c]	P	NA	3	0	0
Ill:	Chicago	P	NA	5	0	1
Ind:	Indianapolis [c]	P	NA	4	0	2
	Central	P	5	6	0	7
	Northeast	P	6	5	0	8
	Northwest	P	7	7	10	9
	Southeast	P	6	6	10	7
	Southwest	P	7	7	0	8
Iowa:	Des Moines [c]	P	NA	4	0	0
	Des Moines	P	5 (2)	5	0 (2)	0
	Iowa City	P	5	5	0	0
	LeMars	P	5	6	0	0
	Little Cedar	P	3	4	NS	2
Kans:	Wichita [c]	P	NA	5	0	1
	Coffeyville	P	3	6	0	7
	Dodge City	P	3	4	0	6
	Falls City, Nebr	R	NS	6	NS	6
	Hays	P	3	6	0	5
	Kansas City	P	6	5	0	8
	Topeka	P	6	7	0	5
	Wichita	P	4	6	0	4
Ky:	Louisville [c]	P	NA	5	0	2
La:	New Orleans [c]	P	NA	7	0	1
Maine:	Portland [c]	P	NA	5	0	15
Md:	Baltimore [c]	P	NA	6	0	8
Mass:	Boston	P	NA	7	0	10
Mich:	Detroit [c]	P	NA	6	0	8
	Grand Rapids [c]	P	NA	7	0	1
	Bay City	P	5	9	0	1
	Charlevoix	P	14	9	0	1
	Detroit	P	9	6	0	0
	Grand Rapids	P	11	9	0	2
	Lansing	P	8	10	0	8
	Marquette	P	9	9	5	8
	Monroe	P	14	12	0	1
	South Haven	P	11	11	0	3
Minn:	Minneapolis [c]	P	NA	7	0	1
	Bemidji	P	6	7	0	0
	Duluth	P	14	16	0	18
	Fergus Falls	P	6	7	0	0
	Little Falls	P	9	17	0	0
	Mankato	P	5	5	0	0
	Marshall	P	3	3	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for December 1973 and 12-month period, January 1973 through December 1973—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
	Minneapolis	P	9	9	0	0
	Rochester	P	NS	6	NS	0
Miss:	Jackson [c]	P	NA	8	0	6
Mo:	Kansas City [c]	P	NA	4	0	0
	St. Louis [c]	P	NA	7	0	1
Mont:	Helena [c]	P	NA	2	0	0
Nebr:	Omaha [c]	P	NA	3	0	0
Nev:	Las Vegas [c]	P	NA	4	0	0
N.H:	Manchester [c]	P	NA	8	0	8
N.J:	Trenton [c]	P	NA	5	0	2
N. Mex:	Albuquerque [c]	P	NA	0	0	0
N.Y:	Buffalo [c]	P	NA	4	0	3
	New York City [c]	P	NA	5	0	3
	Syracuse [c]	P	NA	6	0	1
	Albany	P	4 (3)	4	0	0
	Buffalo	P	5	5	0	0
	Massena	P	5	7	16	11
	New York City	P	3	7	0	0
	Syracuse	P	NS	6	NS	0
N.C:	Charlotte [c]	P	NA	7	0	5
N. Dak:	Minot [c]	P	NA	7	0	0
Ohio:	Cincinnati [c]	P	NA	5	0	3
	Cleveland [c]	P	NA	6	0	2
Okla:	Oklahoma City [c]	P	NA	3	0	0
Oreg:	Portland [c]	P	NA	3	0	1
	Baker	P	NA	NA	[d] 0	1
	Coos Bay	P	NA	NA	[d] 0	4
	Eugene	P	NA	NA	[d] 0	0
	Medford	P	NA	NA	[d] 0	2
	Portland composite	P	NA	NA	[d] 0	0
	Portland local	P	NA	NA	[d] 0	2
	Redmund	P	NA	NA	[d] 0	0
	Tillamook	P	NA	NA	[d] 0	9
Pa:	Philadelphia [c]	P	NA	5	0	2
	Pittsburgh [c]	P	NA	8	0	3
	Dauphin	P	3	4	0	0
	Erie	P	6	6	0	0
	Philadelphia	P	6	3	0	1
	Pittsburgh	P	3	5	0	0
R.I:	Providence [c]	P	NA	5	0	6
S.C:	Charleston [c]	P	NA	6	0	5
	Chapin	R	NA		NA	
	Clemson	R	NA		NA	
	Columbia	R	NA		NA	
	Fairfield	R	NA		NA	
	Hartsville–02	R	NA		NA	
	Hartsville–03	R	NA		NA	
	Lee County	R	NA		NA	
	Oconee County	R	NA		NA	
	Pickens	R	NA		NA	
	Williston	R	NA		NA	
	Winnsboro	R	NA		NA	
S. Dak:	Rapid City [c]	P	NA	5	0	1
Tenn:	Chattanooga [c]	P	NA	6	0	2
	Knoxville [c]	P	NA	0	0	0
	Memphis [c]	P	NA	6	0	2
	Chattanooga	P	NA	8	11	3
	Clinton	R	NA	4	0	3
	Fayetteville	R	NA	7	15	4
	Kingston	R	NA	6	0	0
	Knoxville	P	NA	3	0	0
	Lawrenceburg	R	NA	6	NS	6
	Nashville	P	NA	3	NS	0
	Pulaski	R	NA	6	0	0
	Sequoyah	R	NA	9	NS	0
Tex:	Austin [c]	P	NA	0	0	0
	Dallas [c]	P	NA	3	0	0
Utah:	Salt Lake City [c]	P	NA	2	0	1
Vt:	Burlington [c]	P	NA	4	0	5
Va:	Norfolk [c]	P	NA	6	0	2
Wash:	Seattle [c]	P	NA	2	0	0
	Spokane [c]	P	NA	5	0	0
	Benton County	R	NS	1	NS	0
	Franklin County	R	0	1	0	0
	Longview	R	6	4	12	4
	Sandpoint, Idaho	R	4	5	0	1
	Skagit County	R	7	5	0	0
W. Va:	Charleston [c]	P	NA	6	0	2
Wisc:	Milwaukee [c]	P	NA	4	0	1
Wyo:	Laramie [c]	P	NA	1	0	1

See footnotes at end of table.

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Table 2. Concentration of radionuclides in milk for December 1973 and 12-month period, January 1973 through December 1973—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calgary	P	4	4	2	8
	Edmonton	P	4	5	9	12
British Columbia:	Vancouver	P	5	6	14	13
Manitoba:	Winnipeg	P	3	4	11	10
New Brunswick:	Moncton	P	6	7	8	9
Newfoundland:	St. John's	P	10	13	11	16
Nova Scotia:	Halifax	P	6	7	9	10
Ontario:	Ottawa	P	4	4	9	6
	Sault Ste. Marie	P	8	9	15	17
	Thunder Bay	P	5	6	10	11
	Toronto	P	6	4	7	7
	Windsor	P	3	2	8	6
Quebec:	Montreal	P	5	5	6	7
	Quebec	P	8	8	11	12
Saskatchewan:	Regina	P	4	5	8	8
	Saskatoon	P	6	5	3	7
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal [c]	P	NS	0	NS	13
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	0	1	0	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Montego Bay	P	NS	2	NS	23
Puerto Rico:	San Juan [c]	P	NA	2	0	2
Venezuela:	Caracas	P	0	1	0	2
PMN network average [e]			NA	4	0	3

[a] P, pasteurized milk
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups,

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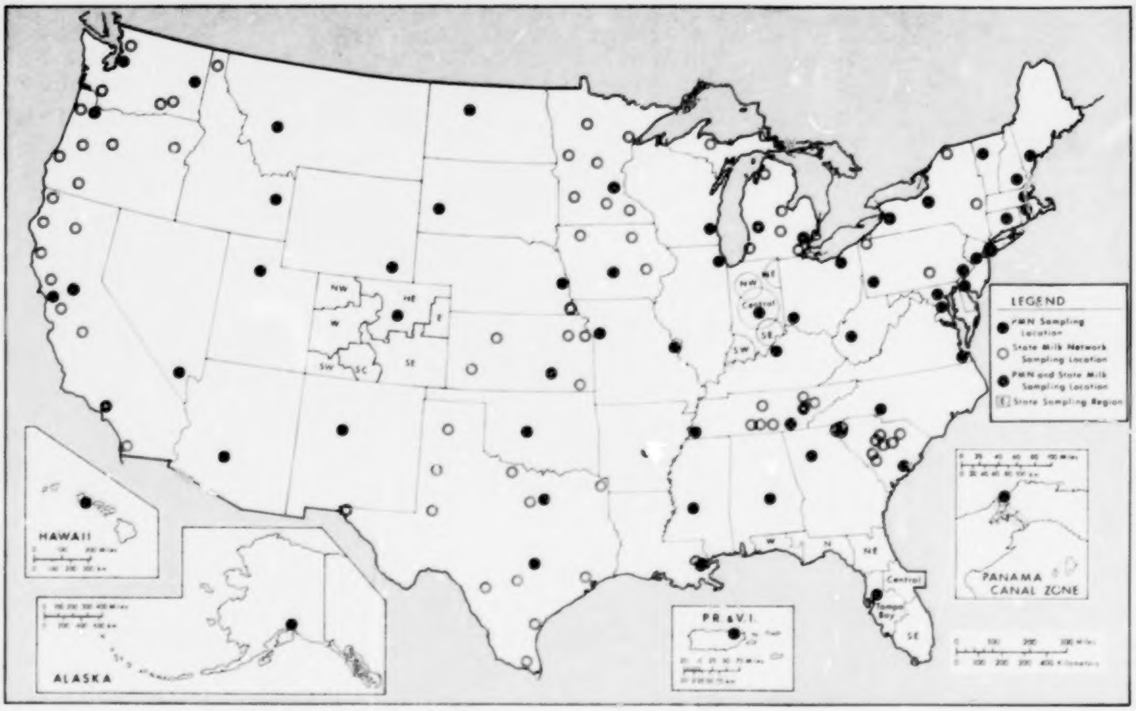
LEGEND
● PMN Sampling Location
○ State Milk Network Sampling Location
● PMN and State Milk Sampling Location
State Sampling Region
HAWAII
ALASKA
PR & V.I.
PANAMA CANAL ZONE
NW
NE
W
E
SW
SC
SE
Central
N
Tampa Bay

Figure 2. State and PMN milk sampling stations in the United States

averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for December 1973 and the 12-month period, January 1973 to December 1973. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for December 1973 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 14 pCi/liter in the United States for December 1973 and the highest 12-month average was 17 pCi/liter (Little Falls, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 38 pCi/liter in the United States for December 1973, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

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Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health

Colorado Department of Health
Laboratory Division

Connecticut Department of Health
Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

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(5) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine-131, cesium-137, strontium-89, strontium-90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(6) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475-488 (September 1968).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Institutional Diet	April–June 1973	March 1974
Strontium-90 in Tri-City Diets	1972	December 1973

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

---

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1971–June 1972	March 1974
New York	July–December 1971	August 1973
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Tritium Surveillance System	April–June 1973	October 1973
Washington	July 1970–June 1971	August 1973

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ERAMS Surface and Drinking Water Components, July–September 1973

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

Present network

The ERAMS Surface and Drinking Water Components are an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 76 quarterly drinking water samples taken from major population centers and selected nuclear facility environs (figure 1). The analyses include (a) tritium on a quarterly basis, (b) gamma scan, gross alpha and gross beta radioactive measurements annually with radium-226 and strontium-90 measurements if the gross alpha or gross beta radioactivity exceed 3 or 10 pCi/liter, respectively, and (c) an annual composite for plutonium-238 and -239 on 19 selected sampling locations. The Surface Water Component consists of 55 quarterly surface water

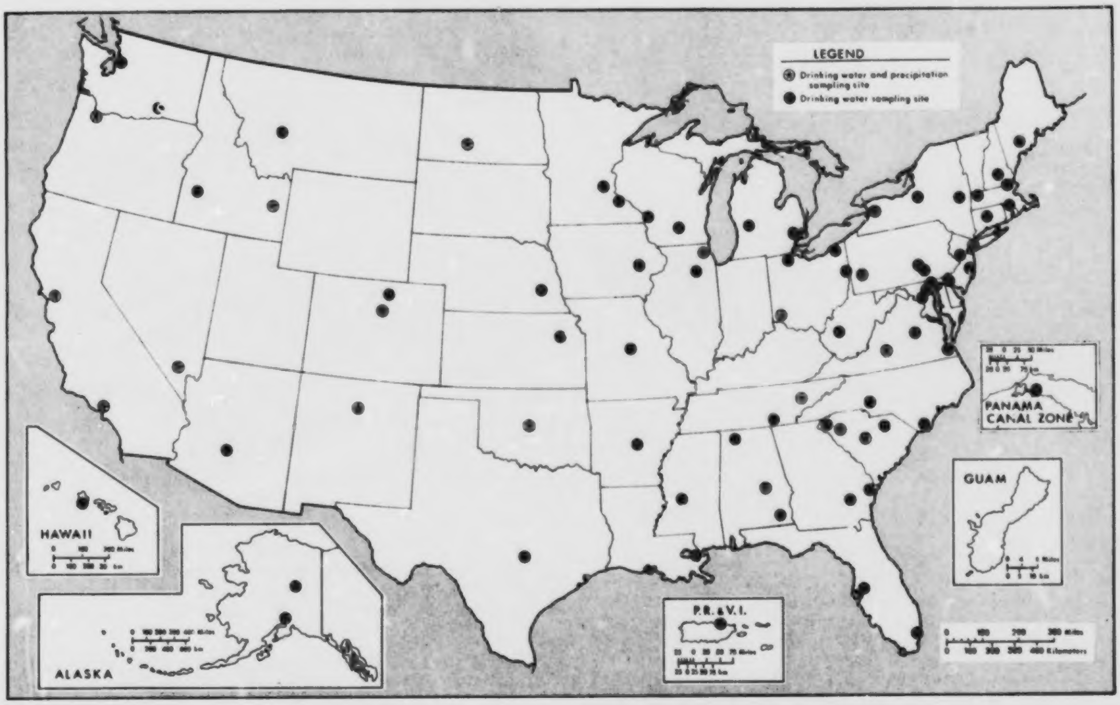
LEGEND
⊛ Drinking water and precipitation sampling site
● Drinking water sampling site
HAWAII
ALASKA
P.R. & V.I.
GUAM
PANAMA CANAL ZONE

Figure 1. ERAMS drinking water component and precipitation sampling locations

samples downstream from nuclear facilities or at a background station (figure 2). The location of the sampling sites was based on all nuclear facilities that were operating, being constructed, or planned through 1976. Tritium analyses are performed quarterly and gamma scans annually. In addition to these components of ERAMS, precipitation samples will be collected at 19 selected locations (figure 1) and tritium measurements are performed on the monthly composite from each station. These 19 locations correspond to air and drinking water sampling locations selected for plutonium analyses. Plutonium-238 and -239 analyses are performed annually on precipitation samples collected in April when elevated levels of rainfall are expected.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the Drinking Water Component stations for July–September 1973. The average tritium concentration was 0.3 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalent from tritium in body water have been based on a relationship derived by Moghissi and Porter (*1*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP recommendation (*2*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*3*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*4*) substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$\dot{H}\ (\text{mrem/year}) = 0.1C\ (\text{nCi/liter})$$

Where $\dot{H}$ is the dose equivalent rate and C represents the tritium concentration in body water in nCi/liter.

It can be assumed for the purpose of calculating dose to members of the population that if the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also if that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

Table 1. ERAMS Drinking Water Component, July-September 1973

Location		Date collected (1973)	Tritium concentration [a] (nCi/liter ±2σ)[b]
Ala:	Dothan	NS	
	Montgomery	7/17	0
	Muscle Shoals	NS	
Alaska:	Anchorage	7/ 2	0.4
	Fairbanks	7/ 2	.6
Ark:	Little Rock	7/ 3	0
Calif:	Berkeley	7/ 5	0
	Los Angeles	7/ 5	.3
C. Z:	Ancon	7/ 9	0
Colo:	Denver	7/20	.7
	Platteville	NS	
Conn:	Hartford	7/ 2	.3
Del:	Wilmington	NS	
D.C:	Washington	7/20	.4
Fla:	Miami	7/ 2	0
	Tampa	NS	
Ga:	Baxley	8/14	0
	Savannah	8/ 8	5.6
Hawaii:	Honolulu	7/23	.2
Idaho:	Boise	7/ 2	.3
	Idaho Falls	8/10	.3
Ill:	Chicago	NS	
	Morris	NS	
Iowa:	Palo	NS	
Kans:	Topeka	7/ 2	0
La:	New Orleans	7/11	.4
Maine:	Augusta	7/ 2	.2
Md:	Baltimore	7/ 2	0
	Conowingo	NS	
Mass:	Lawrence	7/ 2	.2
	Rowe	9/18	.2
Mich:	Detroit	NS	
	Grand Rapids	9/10	0
Minn:	Minneapolis	7/ 3	.4
	Red Wing	9/19	0
Miss:	Jackson	7/ 2	0
Mo:	Jefferson City	7/ 3	0
Mont:	Helena	7/ 3	.5
Nebr:	Lincoln	7/ 6	.4
Nev:	Las Vegas	7/ 2	.7
N.H:	Concord	7/ 2	.4
N.J:	Trenton	7/ 2	.3
	Waretown	8/14	.2
N. Mex:	Santa Fe	7/ 3	.5
N.Y:	Albany	NS	
	Buffalo	7/ 7	.3
	New York City	7/ 2	0
	Syracuse	NS	
N.C:	Charlotte	9/14	.2
	Wilmington	9/28	.3
N. Dak:	Bismarck	7/23	0
Ohio:	Cincinnati	7/ 2	.3
	East Liverpool	NS	
	Painesville	7/ 2	.3
	Toledo	NS	
Okla:	Oklahoma City	7/ 3	0
Oreg:	Portland	7/ 3	0
Pa:	Columbia	NS	
	Harrisburg	7/ 2	0
	Pittsburgh	NS	
P.R:	San Juan	7/ 6	0
R.I:	Providence	7/ 3	0
S.C:	Anderson	9/14	.8
	Columbia	7/ 2	.4
	Hartsville	[c] 10/ 2	0
	Seneca	[c] 10/ 2	.3
Tenn:	Chattanooga	8/ 3	.4
	Knoxville	8/ 6	0
Tex:	Austin	7/ 2	0
Va:	Doswell	NS	
	Lynchburg	NS	
	Norfolk	NS	
Wash:	Richland	NS	
	Seattle	7/ 3	.2
Wisc:	Genoa	9/18	0
	Madison	7/ 2	.2
	Average		0.3

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

[c] Sample collected late.

NS, no sample.

Table 2. ERAMS Surface Water Component, July-September 1973

Location		Water source	Facility	Collection date (1973)	Concentration[a] (nCi/liter ±2σ)[b]
Ala:	Decatur	Tennessee River	Browns Ferry, Sequoyah & Oak Ridge	7/ 6	0.3
	Gordon	Chattahoochie River	Joseph M. Farley	NS	
Ark:	Morrilton	Arkansas River	Arkansas Nuclear One	8/14	.2
Calif:	Clay Station	Folsom S. Canal	Rancho Seco	NS	
	Diablo Canyon	Pacific Ocean	Diablo Canyon	NS	
	Eureka	Humboldt Bay	Humboldt Bay	NS	
	San Onofre	Pacific Ocean	San Onofre	NS	
Colo:	Greely	South Platte River	Fort St. Vrain	7/24	.8
Conn:	East Haddam	Connecticut River	Haddam Neck & Vermont Yankee	7/24	.4
	Waterford	Long Island Sound	Millstone	7/25	0
Fla:	Crystal River	Gulf of Mexico	Crystal River	7/25	0
	Ft. Pierce	Atlantic Ocean	St. Lucie	9/11	0
	Homestead	Biscayne Bay	Turkey Point	7/ 3	0
Ga:	Baxley	Altamaha River	Edwin T. Hatch	8/14	0
Idaho:	Buhl	Snake River	National Reactor Testing Station	7/ 6	0
Ill:	Moline	Mississippi River	Quad-Cities, Genoa. Prairie Island & Monticello	NS	
	Morris	Illinois River	Dresden & Argonne	7/11	.4
	Zion	Lake Michigan	Zion	NS	
Iowa:	Palo	Cedar River	Duane Arnold	NS	
La:	New Orleans	Mississippi River	(Several)	7/ 2	.4
Maine:	Wiscasset	Montseway Bay	Maine Yankee	9/11	0
Md:	Conowingo	Susquehanna River	Peach Bottom & Three Mile Island	7/17	.6
	Lusby	Chesapeake Bay	Calvert Cliffs	7/23	.4
Mass:	Plymouth	Plymouth Bay	Pilgrim	8/ 8	.4
	Rowe	Deerfield River	Yankee	7/ 9	.3
Mich:	Bridgman	Lake Michigan	Donald C. Cook	9/19	.4
	Charlevoix	Lake Michigan	Big Rock Point	7/ 6	.2
	Monroe	Lake Erie	Enrico Fermi	7/ 9	.5
	South Haven	Lake Michigan	Palisades	7/10	.2
Minn:	Monticello	Mississippi River	Monticello	7/ 6	.5
	Red Wing	Mississippi River	Prairie Island & Monticello	9/12	.4
Nebr:	Rulo	Missouri River	Fort Calhoun & Cooper	7/11	.6
Nev:	Boulder City	Colorado River	Background	7/ 3	.7
N.J:	Bayside	Delaware River	Salem	7/16	.2
	Oyster Creek	Toms River	Oyster Creek	8/14	.3
N.Y:	Ossining	Hudson River	Indian Point	7/ 9	.2
	Oswego	Lake Ontario	Nine Mile Point, James A. Fitzpatrick & R. E. Ginna	7/10	.5
	Poughkeepsie	Hudson River	Background	7/11	.3
N.C:	Charlotte	Catawba River	Wm. B. McGuire	7/ 2	.2
	Southport	Atlantic Ocean	Brunswick	NS	
Ohio:	Oak Harbor	Lake Erie	Davis-Besse	NS	
Oreg:	Westport	Columbia River	Trojan & Hanford	NS	
S.C:	Allendale	Savannah River	Savannah River Plant & Oconee	9/26	4.8± .3
	Hartsville	Lake Robinson	H. B. Robinson	7/ 5	.7
Tenn:	Daisy	Tennessee River	Sequoyah & Oak Ridge	8/24	.5
	Kingston	Clinch River	Oak Ridge	7/11	1.0
Tex:	El Paso	Rio Grande	Los Alamos	7/ 2	.3
Vt:	Vernon	Connecticut River	Vermont Yankee	7/ 2	.2
Va:	Mineral	North Anna River	North Anna	NS	
	Newport News	James River	Surry	7/16	0
Wash:	Northport	Columbia River	Background	8/13	.3
	Richland	Columbia River	Hanford	7/ 5	.6
W. Va:	Wheeling	Ohio River	Shippingport & Beaver Valley	7/ 6	.3
Wisc:	Two Creeks	Lake Michigan	Point Beach & Kewaunee	7/16	.4
	Victory	Mississippi River	Genoa, Prairie Island & Monticello	7/ 5	.3
Average					0.4

[a] The minimum detection limit for all samples is 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

The highest individual concentration of tritium observed in drinking water was 5.6 nCi/liter during the third quarter. This corresponds to a dose of 0.6 mrem/yr.

The tritium concentrations for the Surface Water Component samples are given in table 2. The highest tritium concentration was 4.8 nCi/liter for the quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.5 mrem/yr.

The monthly analyses for tritium in precipitation samples at the selected stations are shown in table 3.

Other coverage in *Radiation Data and Reports:*

Period	Issue
July–September 1972	February 1973
October–December 1972	May 1973
January–March 1973	July 1973
April–June 1973	October 1973

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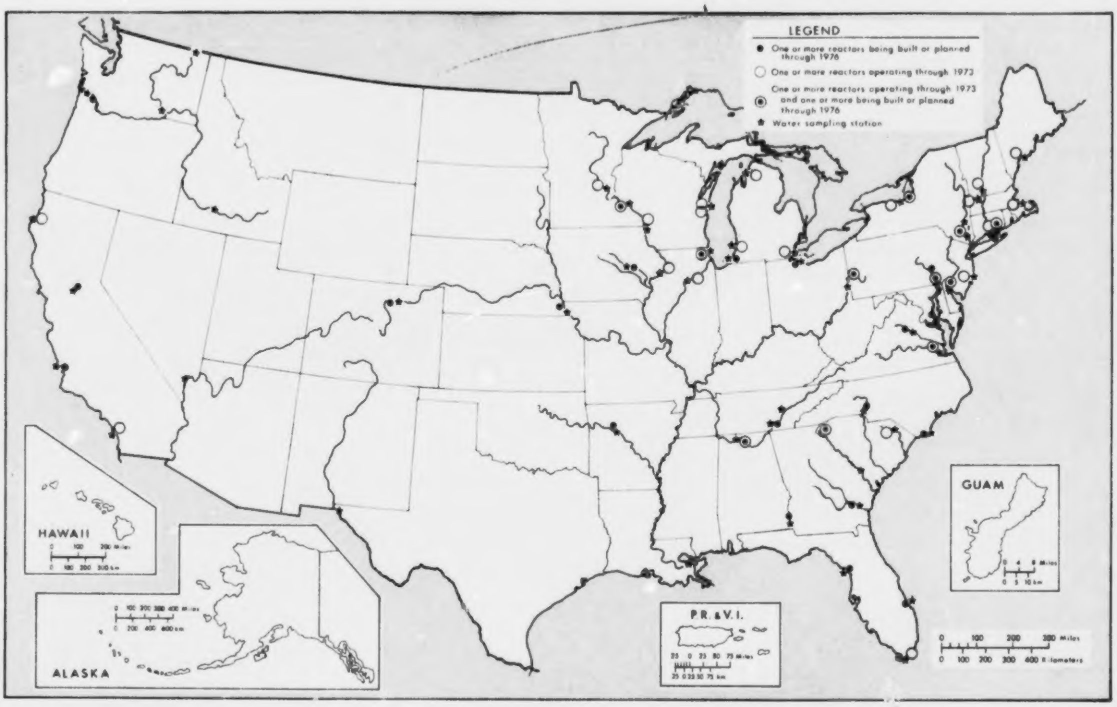
LEGEND
● One or more reactors being built or planned through 1976
○ One or more reactors operating through 1973
◉ One or more reactors operating through 1973 and one or more being built or planned through 1976
★ Water sampling station
HAWAII
ALASKA
P.R. & V.I.
GUAM
0 100 200 300 Miles
0 100 200 300 400 Kilometers

Figure 2. ERAMS surface water component sampling locations

Table 3. Tritium concentration in precipitation July-September 1973

Location		Tritium concentration[a] (nCi/liter ±2σ)		
		July	August	September
Ala:	Montgomery	0.7	0	0
Calif:	Berkeley	NS	NS	0
	Los Angeles	NS	NS	NS
Colo:	Denver	.7	.3	0
Idaho:	Idaho Falls	NS	NS	NS
Ill:	Chicago	NS	NS	NS
Nev:	Las Vegas	NS	NS	NS
N. Mex:	Santa Fe	.4	0	NS
N.Y:	Buffalo	NS	NS	.4
	New York City	NS	NS	NS
N. Dak:	Bismarck	.4	.4	.2
Ohio:	Cincinnati	NS	NS	NS
Okla:	Oklahoma City	NS	NS	NS
Oreg:	Portland	NS	NS	NS
Pa:	Pittsburgh	NS	NS	NS
S.C:	Anderson	NS	NS	NS
	Columbia	1.0	.8	.4
Tenn:	Knoxville	NS	NS	NS
Va:	Lynchburg	NS	NS	NS

[a] The minimum detection limit for these samples is 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

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(*1*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

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(*3*) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Basic radiation protection criteria, NCRP Report No. 39. National Council on Radiation Protection and Measurements, Washington, D.C. 20008 (January 15, 1971).

(*4*) INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS. Radiation quantities and units, ICRU Report No. 19. Washington, D.C. 20014 (July 1972).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports*.

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Krypton-85 in air	July 1970–1972	March 1974
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

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1. Radiation Alert Network
December 1973

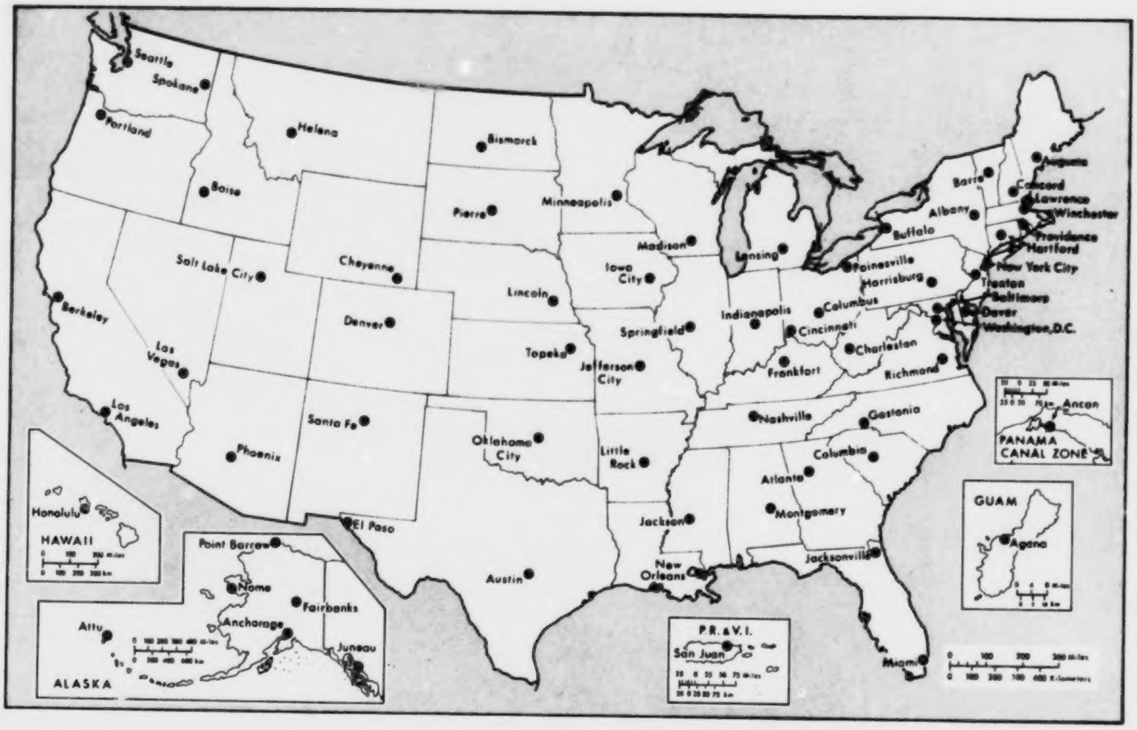
Eastern Environmental Radiation Facility
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during December 1973.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.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Barre
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Concord
Lawrence
Winchester
Providence
Hartford
New York City
Trenton
Baltimore
Dover
Washington, D.C.
Painesville
Harrisburg
Columbus
Indianapolis
Cincinnati
Charleston
Frankfort
Richmond
Salt Lake City
Cheyenne
Lincoln
Iowa City
Springfield
Denver
Topeka
Jefferson City
Berkeley
Las Vegas
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Phoenix
Jackson
El Paso
Austin
New Orleans
Jacksonville
Miami
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Juneau
Attu
ALASKA
P.R. & V.I.
San Juan
PANAMA CANAL ZONE
Ancon
GUAM
Agana

Figure 1. Radiation Alert Network sampling stations

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Table 1. Gross beta radioactivity in surface air and precipitation, December 1973

Station location[a]		Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average[b]	Maximum	Minimum	Average[b]	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	8	1	0	0	0.02	<0.01	0.02	74	0.17
Calif:	Berkeley	8	1	0	0	.03	.01	.02	29	.04
	Los Angeles	8	1	0	1	.07	.02	.05		
Colo:	Denver	8	1	0	0	.05	.03	.04	8	.08
Ind:	Indianapolis	11	4	0	1	.05	.01	.03		
Nev:	Las Vegas	7	2	0	1	.23	<.01	.05		
N. Mex:	Santa Fe	5	1	0	1	.05	.03	.04		
N.Y:	Buffalo	8	0	0	0	.04	.02	.03	13	.01
N. Dak:	Bismarck	4	0	0	0	.06	<.01	.03	9	.04
Ohio:	Columbus	7	1	0	0	.04	<.01	.03		
Okla:	Oklahoma City	0								
Oreg:	Portland	20	0	0	0	.03	<.01	.01		
Pa:	Harrisburg	19	2	0	1	.06	.02	.03		
S.C:	Columbia	8	2	0	0	.08	.01	.04	127	.50
Network summary		121	4	0	0	0.23	<0.01	0.03	43	0.14

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

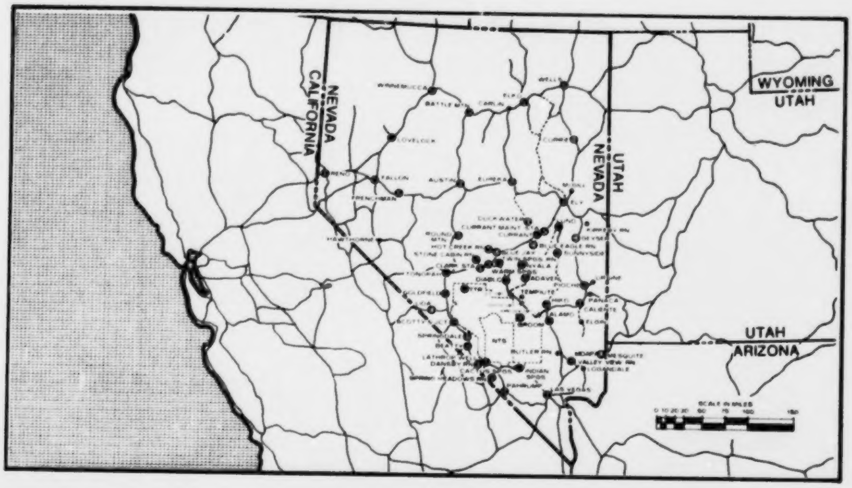

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

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2. Air Surveillance Network
December 1973

National Environmental Research Center—
Las Vegas
Environmental Protection Agency

The Air Surveillance Network (ASN)[2], operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 Western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged over periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports.*

Results

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m^3. For reporting purposes, concentrations less than 1.0 pCi/m^3 are reported to 1 significant figure, and those equal to or greater than 1.0 pCi/m^3 are reported to 2 significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration ($\sim$0.03 pCi/m^3 for a 700 m^3 sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are indicated as follows:

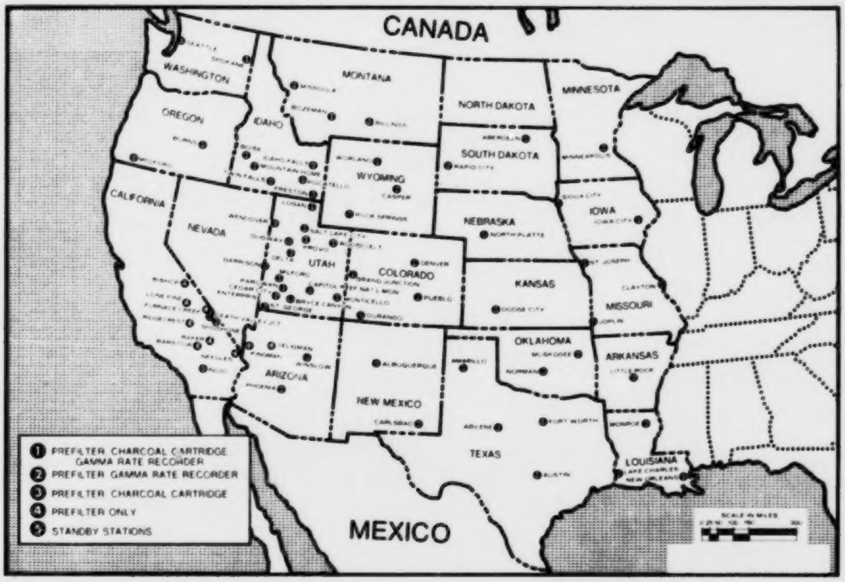
CANADA
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
KANSAS
MISSOURI
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
MEXICO
① PREFILTER CHARCOAL CARTRIDGE GAMMA RATE RECORDER
② PREFILTER GAMMA RATE RECORDER
③ PREFILTER CHARCOAL CARTRIDGE
④ PREFILTER ONLY
⑤ STANDBY STATIONS
SCALE IN MILES

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

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[2] The ASN is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Concentration (pCi/m³)	Reported value of concentration above MDC (pCi/m³)	Reported value of concentration below MDC (pCi/m³)
<0.05	<0.1	<0.1
≥ .05, <.15	.1	< .1
≥ .15	As calculated and rounded	< calculated MDC

As shown by table 2, the highest gross beta concentration at continuously operated stations within the network was 0.7 pCi/m³ at Warm Springs, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during December.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, December 1973

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average ᵃ
Ariz:	Kingman	13	0.2	<0.1	0.1
	Seligman	13	.1	<.1	.1
Calif:	Baker	12	.2	<.1	.1
	Barstow	13	.1	<.1	.1
	Bishop	13	.2	.1	.1
	Death Valley Junction	13	.2	<.1	.1
	Furnace Creek	13	.2	<.1	.1
	Lone Pine	4	.2	.1	.1
	Needles	8	.2	<.1	.1
	Ridgecrest	13	.2	<.1	.1
	Shoshone	13	.1	<.1	.1
Nev:	Alamo	13	.2	<.1	.1
	Austin	13	.2	<.1	.1
	Beatty	13	.1	<.1	.1
	Blue Eagle Ranch (Currant)	13	.2	<.1	.1
	Blue Jay	13	.1	<.1	.1
	Caliente	13	.2	<.1	.1
	Currant Ranch	12	.1	<.1	.1
	Diablo	13	.1	<.1	.1
	Duckwater	10	.1	<.1	.1
	Ely	13	.1	<.1	<.1
	Eureka	13	.1	<.1	.1
	Fallini's Twin Springs Ranch	13	.2	<.1	.1
	Geyser Ranch (Pioche)	10	.2	<.1	.1
	Goldfield	11	.2	<.1	.1
	Groom Lake	9	.1	<.1	.1
	Hiko	13	.2	<.1	.1
	Indian Springs	13	.1	<.1	.1
	Las Vegas	14	.3	<.1	.1
	Lathrop Wells	13	.1	<.1	.1
	Lida	13	.1	<.1	.1
	Lund	13	.1	<.1	.1
	Mesquite	13	.1	<.1	.1
	Nyala	13	.2	<.1	.1
	Pahrump	13	.1	<.1	.1
	Pioche	11	.1	<.1	.1
	Round Mountain	13	.1	<.1	.1
	Scotty's Junction	11	.1	<.1	.1
	Stone Cabin Ranch	13	.1	<.1	.1
	Sunnyside	13	.1	<.1	.1
	Tonopah	13	.1	.1	.1
	Tonopah Test Range	8	.2	<.1	.1
	Warm Springs	9	.7	<.1	.1
	Warm Springs Ranch	14	.2	<.1	.1
Utah:	Cedar City	10	.1	<.1	.1
	Delta	13	.1	<.1	.1
	Garrison	13	.1	<.1	.1
	Milford	12	.1	<.1	.1
	St. George	13	.2	<.1	.1

3. Canadian Air and Precipitation Monitoring Program,[1] December 1973

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for December 1973 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, December 1973

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.04	0.01	0.02	12	0.27
Coral Harbour	4	.04	.01	.03	23	.26
Edmonton	4	.04	.02	.03	9	.40
Ft. Churchill	4	.04	.01	.02	3	21
Fredericton	2	.03	.03	.03	6	.57
Goose Bay	1	.01	.01	.01	4	.38
Halifax	4	.03	.02	.02	8	.53
Inuvik	3	.02	.02	.02	9	.12
Montreal	4	.01	<.01	.01	19	1.20
Moosonee	4	.05	.01	.02	1	.08
Ottawa	3	.02	.01	.01	15	.88
Quebec	3	.02	.01	.01	7	.52
Regina	4	.04	.02	.03	10	.23
Resolute	4	.04	.02	.03	7	.13
St. John's, Nfld	4	.02	.01	.02	NS	NS
Saskatoon	4	.04	.03	.03	6	.23
Sault Ste. Marie	4	.02	.01	.02	9	.70
Thunder Bay	4	.03	.01	.02	11	.95
Toronto	1	.03	.03	.03	18	1.70
Vancouver	4	.01	.01	.01	4	.66
Whitehorse	4	.05	.02	.03	9	.21
Windsor	NS				9	.86
Winnipeg	2	.01	<.01	.01	10	.39
Yellowknife	3	.03	.02	.02	12	.32
Network summary	78	0.05	<0.01	0.02	10	0.51

NS, no sample.

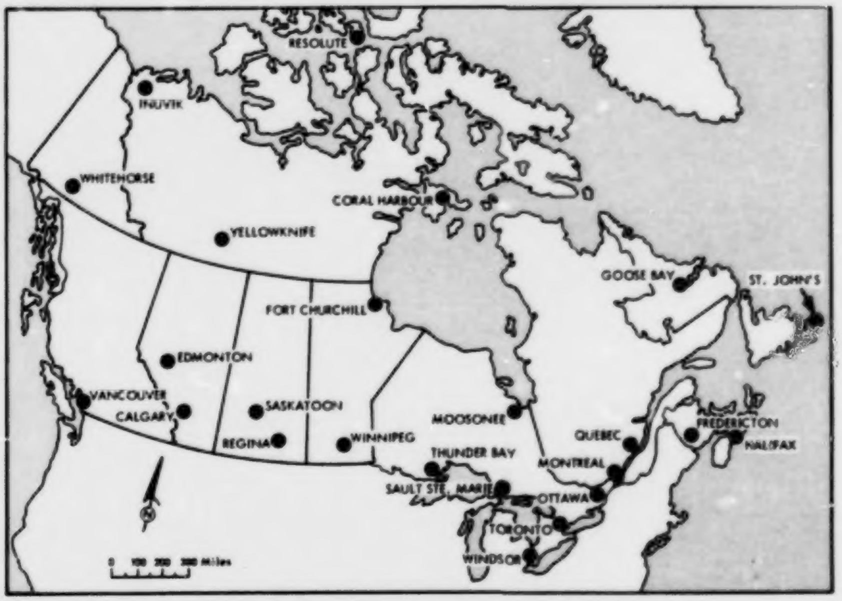
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
0 100 200 300 Miles

Figure 4. Canadian air and precipitation sampling stations

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

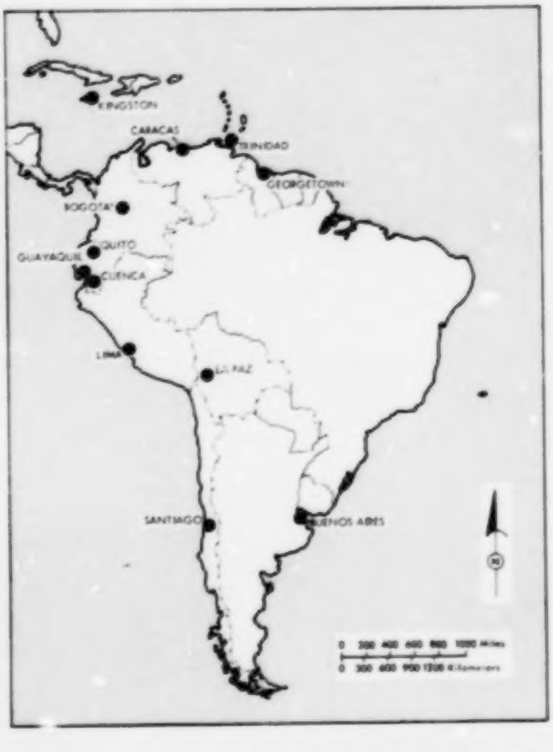

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program
December 1973

Pan American Health Organization and
U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The December 1973 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, December 1973

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	4	0.03	0.01	0.02
Chile:	Santiago	17	.04	.01	.02
Colombia:	Bogota	19	.01	.00	.00
Ecuador:	Cuenca	12	.03	.00	.01
	Guayaquil	18	.05	.00	.01
	Quito	4	.00	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	6	.01	.00	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	7	.01	.00	.00
Pan American summary		87	0.05	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ reported and used in averaging 0.00 pCi/m³.

5. California Air Sampling Program
December 1973

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne par-

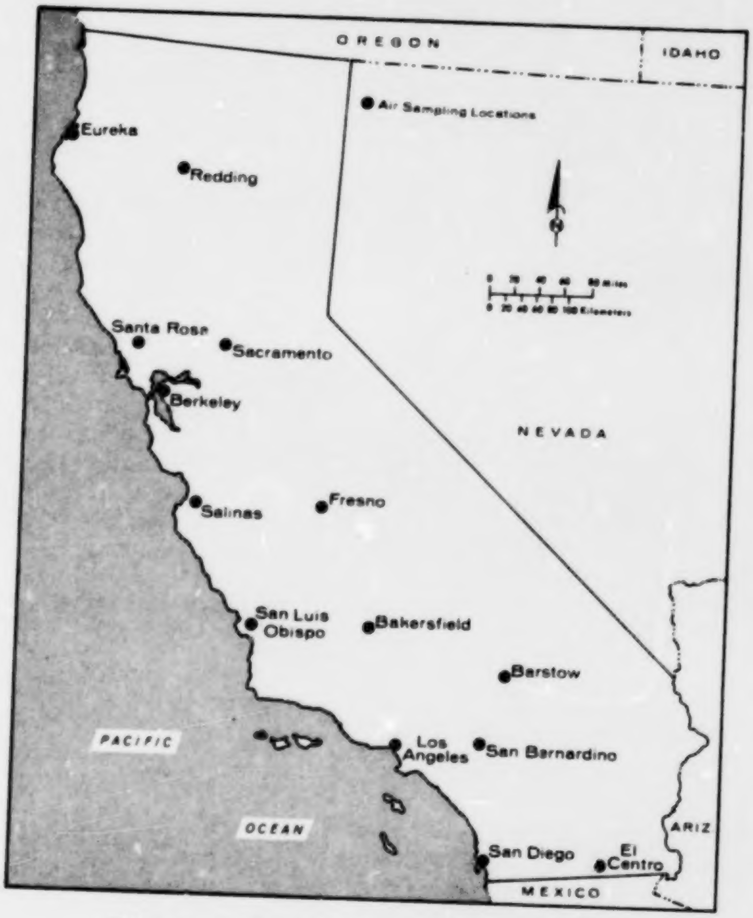
OREGON
IDAHO
Air Sampling Locations
Eureka
Redding
Santa Rosa
Sacramento
Berkeley
NEVADA
Salinas
Fresno
San Luis Obispo
Bakersfield
Barstow
PACIFIC
OCEAN
Los Angeles
San Bernardino
San Diego
El Centro
ARIZ
MEXICO
N

Figure 6. California air sampling program stations

ticulates. The air sampling locations are shown in figure 6.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health where they are analyzed for their radioactive content.

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha

Table 5. Gross beta radioactivity in California air December 1973

Station location	Number of samples	Gross beta radioactivity (pCi/m^3)		
		Maximum	Minimum	Average
Bakersfield	31	1.03	0.04	0.21
Barstow	31	1.01	.06	.30
Berkeley	31	.16	.00	.07
El Centro	30	.42	.05	.14
Eureka	25	.16	.00	.05
Fresno	30	.48	.04	.13
Los Angeles	28	.27	.01	.12
Redding	31	.20	.00	.11
Sacramento	26	.17	.00	.06
Salinas	31	.61	.03	.15
San Bernardino	28	.71	.09	.19
San Diego	31	.43	.04	.13
San Luis Obispo	31	.57	.04	.13
Santa Rosa	31	1.46	.01	.10
Summary	415	1.46	0.00	0.14

and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 5 presents the monthly gross beta radioactivity in air for December. The monthly sample results are presented quarterly.

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6. Mexican Air Monitoring Program July–December 1973

Instituto Nacional de Energía Nuclear
México, D.F.

The Radiation Surveillance Network of Mexico is operated by the Instituto National de Energía Nuclear (INEN).

In the Instituto Nacional de Energía Nuclear, the Comité de Seguridad Radiológica (Radiological Security Committee) (CSR) is responsible for radiological protection. The Environmental Radioactivity Section (Sección de Radioactividad Ambiental) of the CSR is in charge of monitoring and measuring environmental radioactive contamination in general, including radiation in mines, uranium milling plant, and the Nuclear Center of Mexico.

Since radioactivity in air particulates have decreased to very low levels in the past few years, the objective of the air monitoring program has been changed from an alert type of network to emphasize dose assessment.

Measurements will continue in the following 6 areas: México City, D.F., Chihuahua, Ensenada, Torreón, Veracruz and Mérida (figure 7). The sampling and analysis procedures were described previously (*1*).

The maximum, minimum, and average beta radioactivity in surface air from July through December 1973 are presented in table 6. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity at each station (*2*).

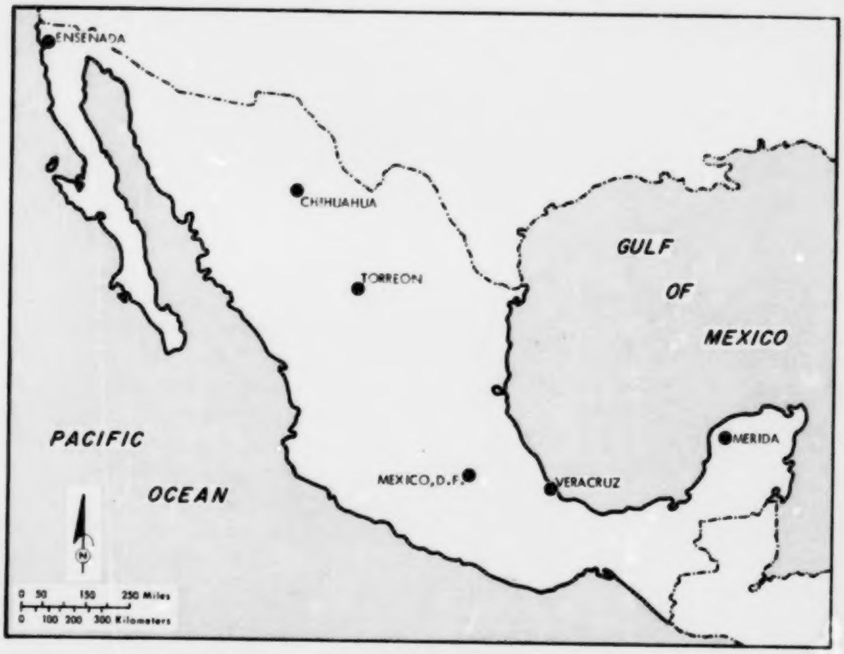

Figure 7. Mexican air sampling locations

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Table 6. Mexican gross beta radioactivity of airborne particulates, July-December 1973

Station	Gross beta radioactivity (pCi/m³)					
	July	Aug	Sept	Oct	Nov	Dec
Chihuahua:						
Maximum	0.23	0.20	0.17	NS	NS	0.13
Minimum	<.03	.04	.04	NS	NS	.06
Average	.12	.11	.11	NS	NS	.09
Ensenada:						
Maximum	.10	.13	NS	NS	NS	NS
Minimum	<.03	.10	NS	NS	NS	NS
Average	.06	.11	NS	NS	NS	NS
Mérida:						
Maximum	.12	.10	.12	0.15	.13	.14
Minimum	.04	.05	.04	.06	.04	.04
Average	.09	.07	.06	.09	.07	.10
México, D.F.:						
Maximum	NS	.14	.06	.22	.05	NS
Minimum	NS	.04	.04	.04	.04	NS
Average	NS	.07	.05	.05	(a)	NS
Torreón:						
Maximum	.27	.20	.12	.14	.16	.15
Minimum	.06	.05	.03	.05	.06	.06
Average	.12	.08	.06	.10	.09	.11
Veracruz:						
Maximum	.26	.17	.11	.16	.21	.15
Minimum	.05	.05	.04	.04	.04	.04
Average	.12	.10	.07	.09	.09	.09

[a] Average not calculated for less than 5 samples.
NS, no sample.

REFERENCES

(*1*) INSTITUTO NACIONAL DE ENERGIA NUCLEAR. Mexican air monitoring program, August–December 1970 and January 1971. Radiol Health Data Rep 12:525–528 (October 1971).

(*2*) VASQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la Republica Mexicana, 1963–1965. Comision Nacional de Energía Nuclear, Direccion General de Seguridad Radiologica (1966).

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7. Plutonium in Airborne Particulates January–March 1973

Office of Radiation Programs
Environmental Protection Agency

The Radiation Alert Network (RAN) of the Division of Atmospheric Surveillance, Environmental Protection Agency, routinely collects airborne particulate samples from 11 selected RAN stations for plutonium analyses. The plutonium analyses were initiated in November 1965, and references to the previous results through December 1969 have been published (*1*).

One-half of each individual air filter from the selected stations is sent to the Eastern Environmental Radiation Facility, Montgomery, Ala. The laboratory analyzes a composite of these samples from each station on a quarterly basis. The results from January–March 1973 are presented in table 7. The minimum detectable activities are 0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively. The volume of air samples varies, generally ranging from 20,000 to 30,000 cubic meters per month.

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Table 7. Plutonium in airborne particulates
January-March 1973

Location		Plutonium-238 (aCi/m^3)	Plutonium-239 (aCi/m^3)	^{239}Pu/^{238}Pu
Alaska:	Anchorage	([a])	([a])	
Ariz:	Phoenix	2.3 ±0.9	19.5 ±2.6	8 ±3
Colo:	Denver	3.1 ± .9	17.8 ±2.3	6 ±2
Hawaii:	Honolulu	1.7 ± .7	10.1 ±1.6	6 ±3
La:	New Orleans	1.0 ± .5	10.3 ±1.7	10 ±5
Md:	Baltimore	1.3 ± .5	8.2 ±1.3	6 ±3
N.Y:	Buffalo	2.0 ± .6	9.4 ±1.4	5 ±2
N.C:	Gastonia	1.8 ± .6	10.4 ±1.5	6 ±2
S. Dak:	Pierre	2.2 ± .7	14.6 ±2.0	7 ±2
Tex:	Austin	2.2 ± .8	20.6 ±2.4	9 ±4
Wash:	Seattle	.6 ± .4	5.3 ±1.2	9 ±6

[a] Insufficient sample volume to obtain detectable levels of plutonium.

REFERENCE

(*1*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–December 1969. Radiol Health Data Rep 11:552–553 (October 1970).

Other coverage in *Radiation Data and Reports:*

Period	Issue
January–March 1972	December 1972
April–June 1972	January 1973
July–September 1972	March 1973
October–December 1972	June 1973

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

A summary of the environmental radioactivity data follow for Rocky Flats, the Sandia Laboratories and the Stanford Linear Accelerator Center.

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[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Rocky Flats Plant[2]
January–December 1971

Dow Chemical Company
Golden, Colo.

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission (AEC). Its location, relative to population centers, is shown in figure 1. The basic goal guiding these operations is total containment of radioactive materials. The environmental survey program is designed to assure that radioactive materials released are below the AEC standards.

The plant is located about 15 miles northwest of Denver, Colo. The surface stratum in this area consists of gravel washed out of the highly mineralized front range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air sampling

To provide further detection and measurement of any accidental release of any contaminated effluents, Rocky Flats maintains an extensive network of continuously operating air sampling devices to monitor contamination levels in the surrounding atmosphere.

Continuous samples are obtained from 12 onsite air sampling stations (figure 2) which sample about 82 cubic meters of air per day

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[2] Summarized from Environmental Monitoring at Major U.S. Atomic Commission Contractor Sites, Rocky Flats Plant, January–December 1971."

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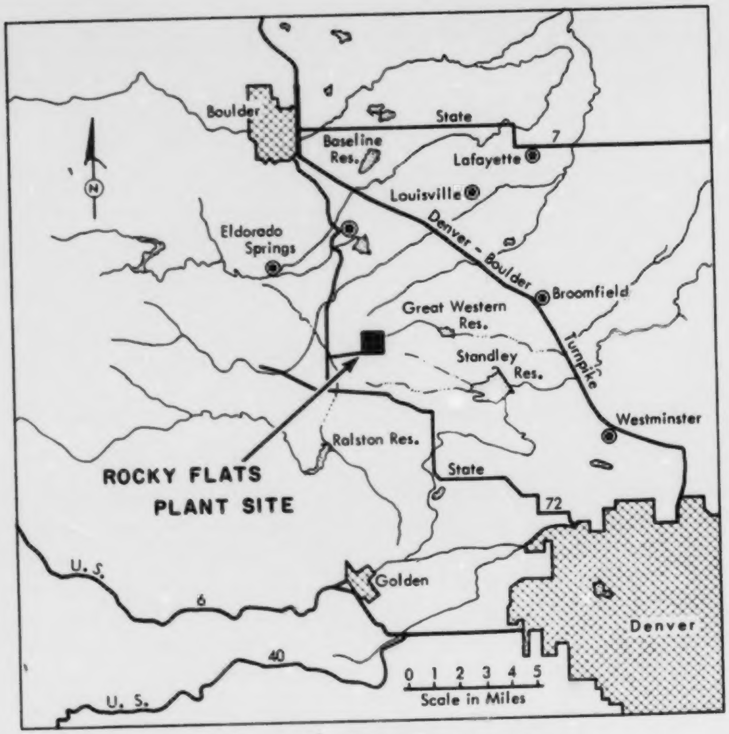
Boulder
State
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Baseline Res.
Lafayette
Louisville
Eldorado Springs
Denver - Boulder Turnpike
Broomfield
Great Western Res.
Standley Res.
Westminster
Ralston Res.
ROCKY FLATS PLANT SITE
State
72
U. S.
6
Golden
Denver
40
U. S.
0 1 2 3 4 5
Scale in Miles
N

Figure 1. Location of Rocky Flats Plant

(the equivalent of 2 cubic feet per minute). These samples are collected and analyzed daily for total long-lived alpha concentrations (which would include plutonium, uranium, and other long-lived alpha emitters) and specifically for beryllium (figure 2).

Twelve high-volume air samplers are located at a radius of about 2 miles from the plant perimeter (figure 3). These samples are collected on a 4-inch filter paper, which is changed daily, composited and analyzed specifically for plutonium. The 437 composite samples for 1971 represent volumes of over 2 000 000 cubic meters (about 70 000 000 cubic feet) of air actually filtered in 1971.

High-volume samples are also taken weekly from Wagner Site (18, figure 3) and from Coal Creek Canyon (11, figure 3), about 2.5 miles southeast and 3 miles west southwest of the plant, respectively. For 1971, the 77 samples taken represent volumes of about 17 000 cubic meters of air (nearly 600 000 cubic feet). These were analyzed specifically for plutonium.

Results for the year indicated a maximum of 0.06 pCi/m^3. High-volume grab samples were also taken to the east of an asphalt pad covering some contaminated soil (former drum storage area in the southeast corner of the plant site proper). The 180 samples taken in 1971 represent over 40 000 cubic meters of air actually filtered and were analyzed for total plutonium content. The results varied from a single sample maximum of 520 fCi/m^3 to a yearly average of 12 fCi/m^3.

Nine low-volume air samplers, programmed to sample for 10 minutes of each hour, are located in Boulder, Broomfield, Denver, Coal Creek Canyon, Golden, Lafayette, Westminster,

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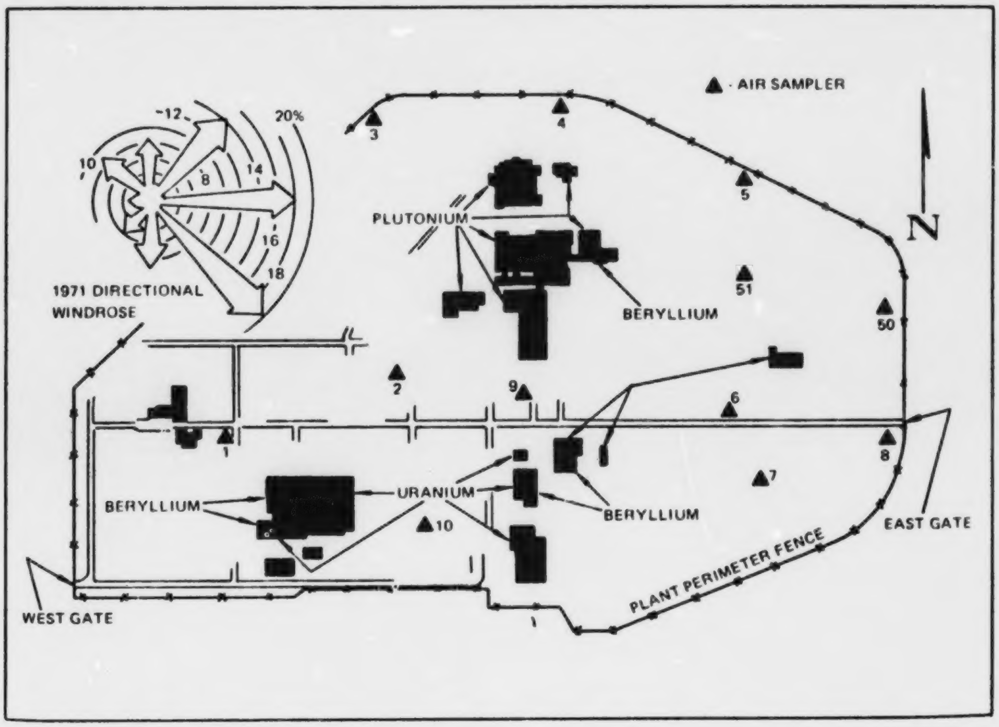
▲ - AIR SAMPLER
12
20%
10
8
14
16
18
1971 DIRECTIONAL WINDROSE
PLUTONIUM
BERYLLIUM
N
3
4
5
51
50
2
9
6
1
8
7
10
BERYLLIUM
URANIUM
BERYLLIUM
EAST GATE
WEST GATE
PLANT PERIMETER FENCE

Figure 2. Onsite air sampling locations and material areas, Rocky Flats Plant

Marshall and Wagner (figure 4). These samples are collected weekly and analyzed for total long-lived alpha activity. The low-volume samplers represent about 44 000 cubic meters of air during 1971.

This complex of air samplers produces nearly 10 000 samples per year. These are analyzed to make certain that effluent levels as well as any redistribution effects are kept well below guideline concentrations. Summaries of these results for 1971 are presented in tables 1, 2, 3, and 4. Onsite air samples varied from a maximum average long-lived alpha concentration (1-month average) of 32.2 fCi/m^3 with a 12-month average of 4.8 fCi/m^3, about 24.0 percent of the standard.

Low-volume, offsite air sample results were also quite low. The programmed samplers indicated a maximum long-lived alpha concentration (1 month average) of 12.3 fCi/m^3 with a yearly average of 4.0 fCi/m^3, about 60 percent of the guidelines. The high-volume, offsite samplers, much more indicative of chronic exposure levels, revealed much lower concentrations. The maximum (1-month plutonium average) was 4.6 fCi/m^3 whereas the average for the year was 0.24 fCi/m^3, about 1.2 percent of the guideline.

Data from the air sampling network indicate that the average contaminant concentrations in air effluents from Rocky Flats were below the established standards.

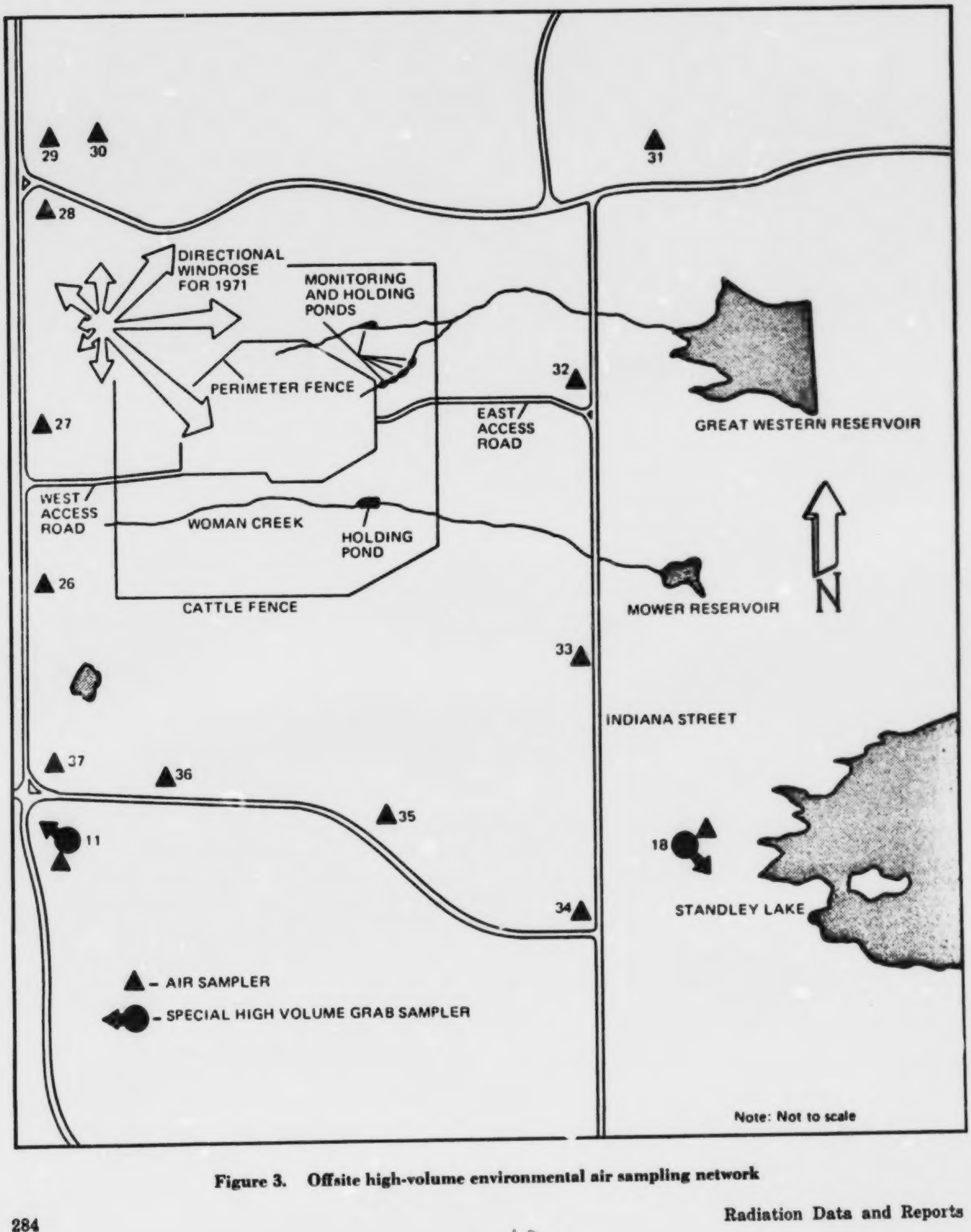
29
30
31
28
DIRECTIONAL
WINDROSE
FOR 1971
MONITORING
AND HOLDING
PONDS
PERIMETER FENCE
32
EAST
ACCESS
ROAD
GREAT WESTERN RESERVOIR
27
WEST
ACCESS
ROAD
WOMAN CREEK
HOLDING
POND
26
CATTLE FENCE
MOWER RESERVOIR
N
33
INDIANA STREET
37
36
35
11
18
34
STANDLEY LAKE
- AIR SAMPLER
- SPECIAL HIGH VOLUME GRAB SAMPLER
Note: Not to scale

Figure 3. Offsite high-volume environmental air sampling network

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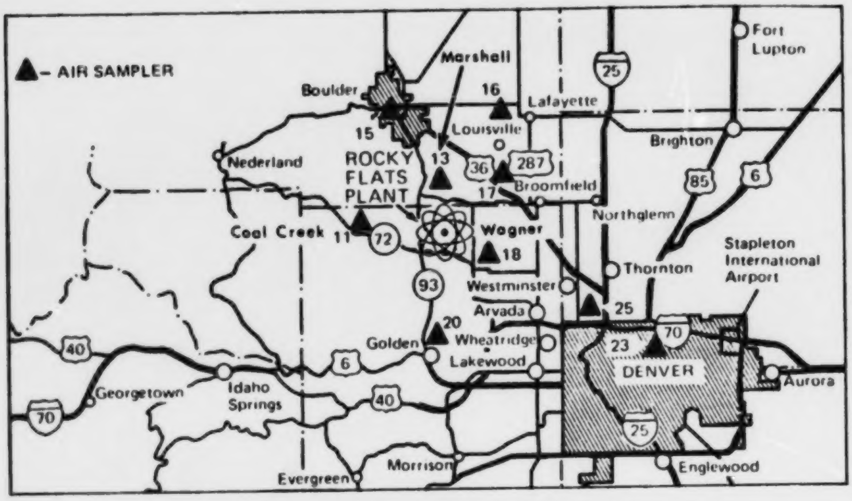
▲ - AIR SAMPLER
Fort Lupton
Marshall
Boulder
16
Lafayette
15
Louisville
25
ROCKY FLATS PLANT
13
36
287
Brighton
Nederland
Broomfield
17
85
6
Northglenn
Coal Creek
11
72
Wagner
18
Thornton
Stapleton International Airport
93
Westminster
Arvada
25
20
Golden
Wheatridge
23
70
40
6
Lakewood
DENVER
Aurora
Georgetown
Idaho Springs
40
70
25
Evergreen
Morrison
Englewood

Figure 4. Programmed environmental air sampling network

Table 1. Total long-lived alpha (uranium, plutonium, and naturally occurring alpha emitters) in onsite air samples, Rocky Flats Plant, January-December 1971

Location [a]	Average concentration (fCi/m³)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	4.4	3.3	4.5	3.6	5.7	4.7	3.3	4.0	4.5	4.9	3.5	3.5
2	4.5	4.4	3.9	4.6	4.6	2.5	2.5	4.9	3.1	4.4	4.0	4.4
3	3.3	2.8	3.3	5.9	5.2	4.3	5.5	6.6	7.0	5.2	5.0	3.9
4	2.0	4.4	4.7	6.6	4.2	3.6	4.6	4.1	3.5	3.4	3.4	3.2
5	1.7	4.0	3.2	3.6	4.7	5.4	5.3	2.6	3.4	5.8	6.9	3.3
6	3.1	3.0	2.8	3.7	5.2	3.0	14.6	2.0	3.2	2.9	6.8	2.7
7	8.2	6.6	5.4	8.2	4.3	4.3	2.7	3.4	2.2	3.4	1.7	4.3
8	5.8	6.9	7.8	32.2	9.0	8.1	10.5	11.0	5.6	12.8	11.4	6.6
9	4.3	4.0	4.1	3.9	3.6	3.8	4.4	3.6	2.6	2.7	1.3	3.8
10	4.6	5.2	4.1	6.0	4.2	5.6	3.4	3.0	4.0	6.3	4.1	3.5
50	4.2	2.6	4.1	8.5	4.8	7.1	5.3	8.6	6.1	7.6	6.4	3.3
51	4.4	5.1	3.6	6.6	4.6	3.3	2.5	2.0	4.1	5.4	4.4	5.2

1a. Summary of total long-lived alpha in onsite air samples, Rocky Flats Plant, 1971

Location [a]	Total number of samples	Number of samples less than detectable level	Maximum (fCi/m³)	Average (fCi/m³)	Percent of standard [b]
1	242	125	21.8	4.2	21.0
2	239	140	42.0	4.0	20.0
3	244	124	21.8	4.8	24.0
4	243	142	33.3	3.9	19.5
5	244	132	22.8	4.1	20.5
6	244	161	272.3	4.3	21.5
7	244	136	82.2	4.5	22.5
8[c]	243	81	565.3	10.2	51.5
9	242	147	21.9	3.5	17.5
10	237	125	22.8	4.5	22.5
50	243	120	143.6	5.7	28.5
51	244	135	34.1	4.3	21.5
Yearly summation	2 909	1 568	565	4.8	24.0

[a] See figure 2.

[b] Applicable standard (soluble plutonium-239) = 20 fCi/m³.

[c] This sampler is located within the strongest, most frequent wind vector, and is adjacent to the asphalt pad covering some contaminated soil. The large volumes of dirt thus seen by this sampler may be indicative of resuspension mechanisms. It is worthy of note that this, the highest concentration location, is still only about 50 percent of the applicable standard when stated in terms of yearly averages.

Note: For averaging purposes, all samples below minimum detectable amounts (MDA) were assigned a fractional value (number of samples >MDA divided by total number of analyses) of the appropriate MDA.

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Table 2. Total long-lived alpha (uranium, plutonium, and naturally occurring alpha emitters) in offsite low volume programmed air samples, Rocky Flats Plant, January-December 1971

Location[a]	Average concentration (fCi/m³)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boulder (15)	4.0	4.1	0.5	5.9	7.2	6.1	3.5	8.9	6.0	6.7	6.7	3.9
Broomfield (17)	3.2	6.2	5.6	5.1	3.0	2.8	.4	5.4	3.4	.1	3.1	3.8
Coal Creek (11)	.1	4.0	2.2	5.6	2.5	3.5	ND	ND	.2	2.4	2.7	2.1
Denver (23)	2.0	1.3	8.9	5.0	3.7	4.8	2.3	7.7	5.6	1.3	3.8	2.8
Golden (20)	3.1	5.0	5.4	5.7	5.7	ND	ND	.8	10.8	3.8	2.1	1.8
Lafayette (16)	7.3	7.2	6.4	8.5	5.7	5.2	3.0	4.3	7.9	3.0	2.1	6.7
Marshall (13)	4.3	2.3	ND	ND	2.6	.2	2.0	3.7	3.8	1.5	ND	.2
Wagner (18)	2.6	ND	2.9	8.3	9.2	12.3	6.3	7.1	5.5	2.9	2.7	5.0
Westminster (25)	2.7	.1	2.7	6.7	.2	7.3	4.9	5.4	1.4	5.0	2.6	6.2

2a. Summary of long-lived alpha concentrations, low-volume programmed samples, 1971

Location[a]	Number of samples	Number of samples less than detectable level	Concentration (fCi/m³)					
			January-June 1971		July-December 1971		January-December 1971	
			Maximum	Average	Maximum	Average	Average	Percent of standard[b]
Boulder (15)	48	23	12.8	5.0	17.4	6.1	5.6	82.9
Broomfield (17)	48	32	13.4	4.5	12.8	1.9	3.7	55.2
Coal Creek (11)	48	39	12.9	3.0	8.3	1.3	2.1	32.0
Denver (23)	47	27	16.0	1.6	9.8	4.1	3.8	57.2
Golden (20)	48	34	13.4	4.4	36.8	1.4	4.0	59.3
Lafayette (16)	48	23	16.0	7.0	16.3	1.9	6.0	89.6
Marshall (13)	47	37	8.2	1.7	7.0	1.9	1.8	27.6
Wagner (18)	48	29	19.7	1.3	16.7	1.1	5.7	84.9
Westminster (25)	44	35	27.0	3.1	29.8	4.7	3.9	58.4
Summary	426	275	27.0	4.3	36.8	3.7	4.0	60.0

[a] See figure 4.
[b] Applicable standard (unidentified alpha emitters) is 6.7 fCi/m³.
ND, nondetectable.

Dustfall samples

In addition to the air samples obtained, specially designed trays atop all the offsite air stations collect dustfall samples for specific plutonium analysis. In addition, more remote samples are collected from locations near Berthoud and from Castle Rock. Table 5 tabulates these results for the year. All samples are collected on a bimonthly basis, and represent fallout from atmospheric weapons testing, and, of course, any contribution from Rocky Flats. Castle Rock and Berthoud samples are collected to provide an indication of plutonium in dustfall samples from background. The values obtained in this extensive sampling pro-

Table 3. Plutonium concentrations in high volume offsite samples February-December 1971[a]

Location[b]	Concentration (fCi/m³)										
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
26	0.14	0.20	0.22	0.24	0.19	0.07	0.23	0.12	0.22	0.17	0.03
27	.08	.22	.12	.25	.27	.15	.31	.14	.46	(c)	.47
28	.17	.19	.12	.20	.27	.13	.29	.33	.12	(c)	(c)
29	.19	.16	.11	.23	.41	.28	.33	.22	.14	.17	.24
30	.11	.16	.10	.26	.30	.19	.24	.12	(c)	(c)	(c)
31	.09	.15	.22	.33	.28	.19	.39	.23	.14	.20	.30
32	.19	.33	.16	.28	1.24	.11	.28	.26	1.93	(c)	.08
33	.25	.30	.20	.33	.30	.18	.26	.21	.09	.13	.22
34	.20	.25	.14	.31	.39	.12	.22	ND	(c)	(c)	.17
35	.16	.21	.16	.27	.29	.16	.22	.16	.31	ND	.39
36	.11	.35	.21	.25	.26	.12	.24	.22	.20	.17	.10
37	.16	.92	.30	.27	.28	.11	.32	.24	4.60	ND	(c)

3a. Summary of plutonium concentrations in high volume offsite samples, 1971

Location	Concentration (fCi/m³)							
	February-June 1971		July-December 1971		Totals for year			
	Maximum concentration single sample	Average	Maximum concentration single sample	Average	Average concentration	Percent of standards	Total number of samples	Number below detection limit
26	0.41	0.21	0.41	0.13	0.17	0.84	41	11
27	.44	.20	3.43	.24	.24	.21	35	5
28	.44	.19	.73	.25	.21	1.06	33	2
29	.68	.22	1.32	.29	.26	1.30	44	5
30	.50	.19	.43	.20	.19	.97	30	3
31	.64	.23	.59	.24	.24	1.18	43	2
32	4.28	.46	1.93	.22	.36	1.80	34	4
33	.63	.28	.83	.19	.23	1.16	44	4
34	.92	.26	.28	.16	.23	1.14	28	4
35	.43	.22	.66	.21	.22	1.08	37	5
36	.70	.25	.87	.18	.21	1.05	43	6
37	2.22	.41	4.64	.23	.34	1.70	32	6
Yearly summation							444	57
Total average					0.24	1.20		

[a] This network of samplers began operation in February 1971.
[b] See figure 3.
[c] Air samplers inoperative due to pump failure.
ND, nondetectable.

Note: For averaging purposes, all samples below minimum detectable amounts (MDA) were assigned a fractional value (number of samples >MDA divided by total number analyses) of the appropriate MDA.

Applicable standard (soluble plutonium-239) is 20 fCi/m³.

gram are on the same order of magnitude as reported for worldwide fallout measurements (*1*). These levels represent no health or safety hazard. There is possibly some insignificant but nonetheless real contribution from Rocky Flats. Studies are now underway to determine what (if any) contribution is directly attributable to Rocky Flats.

Water samples

Rocky Flats is drained by three streams: North and South Walnut Creeks to the north of the plant site, and Woman Creek to the south. For reference, North Walnut Creek is classified as the plant's "A" drainage, South Walnut Creek as the "B" drainage, and Woman Creek as the "C" drainage.

Sanitary and process waste waters are released after treatment to South Walnut Creek through a series of four holding ponds (ponds B–1, B–2, B–3, B–4). Effluents released through the sewage plant meet all water quality standards as established by the Colorado Department of Health (*2*) or the U.S. Public Health Service Drinking Water Standards Act (1962)

Table 4. Plutonium concentrations in special high-volume air samples, Rocky Flats Plant, January-December 1971

Location of grab samples	Concentration (fCi/m³)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Onsite:[a]												
903-20	0.93	0.85	2.36	1.09	1.36	2.72	1.06	2.50	7.10	2.59	3.01	5.45
903-15	.55	1.38	4.15	1.30	.38	1.54	6.96	7.89	110.00	18.51	.41	.42
903-10	.91	1.43	4 03	.94	.50	1.24	.87	1.10	168.19	39.11	1.52	3.17
903-5	.45	1.02	.40	1.23	.79	21.16	.81	1.56	125.6	NS	4.31	2.63
Offsite:												
Wagner	.64	1.96	1.76	2.73	1.45	1.95	2.41	7.22	13.24	14.37	1.29	1.26
Coal Creek	NA	4.27	1.38	1.86	1.31	12.09	1.66	3.59	1.42	.38	1.17	2.83

4a. Yearly summation of plutonium concentrations in special high-volume air samples, RFP, January-December 1971

Location	Single sample maximum (fCi/m³)	Average concentration (fCi/m³)	Percent of standard[b], [c]	Number of samples	Number less than detection limits
Onsite:					
903-20	18.00	2.4	4.0	49	13
903-15	408.40	14.676	24.5	49	20
903-10	516.40	22.319	37.2	50	16
903-5	49.60	3.371	5.6	41	14
Total (averages)		11.5	19.1	189	63
Offsite:					
Wagner	49.50	3.438	17.2	44	10
Coal Creek	60.20	3.142	15.7	38	11
Total (averages)		3.3	16.6	82	21

[a] Onsite grab samples taken east of asphalt pad covering contaminated soil on plant site.
[b] Standard for onsite samples is taken as 60 fCi/m³.
[c] Offsite standard, 20 fCi/m³.
NA, no analysis.

(*3*). The overflow from the pond system (Ponds B–1 through B–4) flows into Great Western Reservoir.

Continuous flow into this reservoir is comprised mainly of liquid wastes from Rocky Flats and makes up a small portion of the drinking water for the community of Broomfield.

Holding ponds are also located on North Walnut Creek (Pond A) and on Woman Creek (Pond C), but no effluents are discharged directly into these holding ponds.

Daily water samples are collected from Pond B–4, and three times weekly from the Ponds A and C. These samples are composited into a weekly sample and analyzed for their gross alpha (uranium and plutonium) content as well as specifically for plutonium and for americium.

Tap water samples from the surrounding communities (Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Louisville, Thornton, and Westminster) and water samples from four reservoirs in the area are collected every 2 weeks, and analyzed specifically for gross alpha and plutonium. Standley and Great Western Reservoir water samples are also analyzed for americium.

Weekly grab samples are taken from Walnut Creek below the confluence of the North and South branches and analyzed for gross alpha and specifically for plutonium and americium content. As a further safeguard, nearly all waters in the immediate vicinity are surveyed semiannually and analyzed for gross alpha (uranium and plutonium) and for plutonium content. There are 34 such bodies of waters

Table 5. Plutonium in dustfall samples, 1971

Location	Number of samples	Number of samples less than detection limit	Sample days	Maximum (single sample) concentration (pCi/m²)	Total deposition (pCi/m²)	Deposition rate (pCi/m²/month)
Arvada	23	9	362	16.11	76.45	6.[illegible]5
Berthoud [a]	7	2	316	5.58	12.98	1.23
Broomfield	22	12	348	28.88	74.48	6.42
Boulder	22	14	334	28.59	85.69	7.70
Castle Rock [a]	9	7	355	2.46	5.46	.55
Coal Creek	20	12	306	21.66	51.26	5.02
Denver	23	11	341	53.87	118.27	10.41
Eastlake	23	11	362	10.59	49.84	4.13
Golden	22	9	348	[b] 174.16	[b] 219.55	[b] 18.98
Lafayette	22	13	362	35.83	82.50	6.84
Marshall	23	11	362	67.70	149.04	12.35
Superior	21	8	334	16.11	74.20	6.66
Wagner	20	8	313	13.17	70.39	6.75
Westminster	23	9	362	[b] 1127.11	[b] 1168.50	[b] 96.84

[a] Background samples.
[b] Based on highly suspect data.

surveyed, 18 within 5 miles of the plant site and 16 at distances greater than 5 miles.

The most restrictive standard, that for soluble plutonium-239, is 1.67 nCi/liter in terms of yearly averages to a suitable sample of a population. Gross alpha concentrations in samples from B–4 pond had a maximum of 36.64 pCi/liter, and a yearly average of 11.79 pCi/liter. These gross alpha concentrations are contributions from both plutonium and uranium. All other naturally occurring long-lived alpha emitters are removed from the samples during the analytical procedure.

Total maximum plutonium concentration in pond B–4 was 7.23 pCi/liter with a yearly average of 1.89 pCi/liter. Americium-241 maximum was 3.07 pCi/liter with a yearly average of 1.12 pCi/liter.

Grab samples from Pond A showed a maximum gross alpha concentration of 28.89 pCi/liter, with a yearly average of 7.30 pCi/liter. Pond C showed similar low concentrations with a yearly maximum (gross alpha) of 23.64 pCi/liter and a yearly average of 6.14 pCi/liter.

Those grab samples taken at the confluence of North and South Walnut Creeks showed a maximum gross alpha of 56.05 pCi/liter. Maximum plutonium concentration found was 8.47 pCi/liter, and maximum americium was 1.67 pCi/liter. Average gross alpha was 12.17, average plutonium, 2.26 pCi/liter and average americium, 0.60 pCi/liter.

Tap water results averaged 3.32 pCi/liter for gross alpha radioactivity with a maximum of 18.58 pCi/liter gross alpha activity. Gross alpha concentrations in the reservoirs averaged 6.76 pCi/liter with a maximum individual measurement of 30.40 pCi/liter at Ralston Reservoir.

Average plutonium concentrations, summarized in tables 6–11 show that all water samples, from tap water, reservoirs, and holding ponds were 1 000 to 10 000 times less than the most restrictive standard for soluble plutonium.

Sediment samples

Sediment samples from the four major reservoirs are collected semiannually and more frequent sediment samples are taken from each of the six holding ponds. Additional samples are also taken from Walnut and Woman Creeks. These samples are taken to a depth of 4 centimeters. No specific standard now exists for plutonium in sediment samples. The results, tabulated in table 12, indicate a maximum of 641.67 pCi/g (dry weight) within the controlled area. The maximum concentration found outside the controlled access area of the plant site was 7 pCi/g.

Soil samples

The Rocky Flats Health Physics Department has maintained an extensive soil sampling program on a routine basis since mid-1969. Prior

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Table 6. Radioactivity in holding pond B–4 (effluent wastewater), Rocky Flats Plant, January-December 1971

Month (1971)	Number of samples	Effluent volume (Ml)	Uranium and plutonium			Plutonium			Americium		
			Concentration (pCi/liter)		Total release (mCi)	Concentration (pCi/liter)		Total release (mCi)	Concentration (pCi/liter)		Total release (mCi)
			Maximum	Average		Maximum	Average		Maximum	Average	
January	4	36.01	36.64	14.33	0.516	4.01	2.29	0.082	3.07	3.07	0.111
February	4	34.85	27.73	24.74	.862	7.23	2.92	.101	1.36	1.20	.042
March	4	49.18	19.29	13.15	.647	4.32	2.86	.141	2.67	1.89	.093
April	5	41.21	19.98	14.75	.608	5.23	2.99	.123	2.39	1.61	.066
May	4	32.32	19.06	12.54	.406	4.59	2.63	.085	2.26	.94	.030
June	5	28.15	10.30	8.33	.234	2.61	1.60	.045	2.18	1.37	.039
July	4	23.96	8.95	5.79	.139	6.09	3.20	.076	1.29	1.08	.025
August	4	30.47	18.75	11.34	.346	2.77	1.05	.032	.52	.42	.013
September	5	33.69	11.19	6.93	.233	2.04	1.29	.043	1.08	.65	.022
October	4	42.64	5.75	5.61	.239	1.59	1.01	.043	.14	.06	.003
November	4	47.61	15.08	10.67	.508	.98	.59	.028	1.30	.76	.036
December	5	53.79	18.59	11.48	.618	1.56	1.09	.059	NA	NA	NA

6a. 1971 summary of radioactivity in holding pond B–4 (effluent wastewater) Rocky Flats Plant

Month (1971)	Number of samples	Uranium and plutonium			Plutonium			Americium[b]		
		Concentration (pCi/liter)		Total release (mCi)	Concentration (pCi/liter)		Total release (mCi)	Concentration (pCi/liter)		Total release (mCi)
		Maximum	Average		Maximum	Average		Maximum	Average	
January–June	26	36.64	14.76	3.273	7.23	? 61	0.578	3.07	1.72	0.381
July–December	26	18.59	8.97	2.082	6.09	1.21	.282	1.29	.55	.127
Summary	52	36.34	11.79	5.355	7.23	1.89	0.860	3.07	1.12	0.508

[a] Yearly summation pond B–4 (effluent wastewater: total volume 1971 = 453.91 Ml).

[b] July-December 1971 americium average calculated from 5-month data; July-December release = average concentration x July-December effluent; summary average = 0.508 divided by total effluent.

NA, no analysis.

Table 7. Radioactivity in holding ponds A and C, Rocky Flats Plant, January-December 1971

Month (1971)	Pond A				Pond C			
	Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)		Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)	
			Uranium and plutonium	Plutonium			Uranium and plutonium	Plutonium
January	4	0	7.07	0.51	4	0	6.98	0.26
February	4	0	8.88	.42	4	0	10.98	.72
March	4	0	7.09	.31	4	0	5.66	.25
April	5	0	6.62	1.12	5	0	6.44	1.13
May	4	0	6.23	.85	4	0	6.73	.31
June	5	0	4.63	1.21	5	0	4.52	.94
July	4	0	3.93	.97	4	0	4.19	.47
August	4	0	7.27	.66	4	0	8.63	.50
September	5	0	6.13	.51	5	0	6.90	.42
October	4	0	6.85	.32	4	0	4.32	.48
November	3	0	9.04	.38	4	0	3.80	.79
December	5	0	13.75	.79	5	0	4.47	.41

7a. 1971 summary of radioactivity in holding ponds A and C, Rocky Flats Plant

Location	Uranium and plutonium					Plutonium				
	Number of samples[a]	Concentrations (pCi/liter)			Percent of AEC standard[b]	Number of samples[a]	Concentrations (pCi/liter)			Percent of AEC stand-rd[c]
		Maximum	Minimum	Average			Maximum	Minimum	Average	
Pond A	51	28.89	1.33	7.30	0.11	49	2.76	0.04	0.68	0.04
Pond B	51	29.64	0.82	6.14	0.09	52	3.84	0.06	0.58	0.03

[a] The number of samples less than detectable limit for Ponds A and C in 1971 was 0.

[b] Gross alpha standard is $\frac{C_U}{MPC_U} + \frac{C_{Pu}}{MPC_{Pu}} \leq 1$ where: MPC for uranium = 10 000 pCi/liter; MPC for plutonium = 1 667 pCi/liter.

[c] The plutonium standard is 1 667 pCi/liter.

Table 8. Radioactivity in effluent waste water (Walnut Creek at Indiana Road), RFP, January-December 1971

Month (1971)	Uranium and plutonium				Plutonium				Americium			
	Number of samples	Concentration (pCi/liter)			Number of samples	Concentration (pCi/liter)			Number of samples	Concentration (pCi/liter)		
		Maximum	Minimum	Average		Maximum	Minimum	Average		Maximum	Minimum	Average
January	2	19.71	2.85	11.28	2	2.68	1.28	1.98	1	0.73	0.73	0.73
February	4	30.06	13.69	19.30	4	8.47	.86	4.36	3	1.67	.68	1.25
March	5	11.53	4.76	8.91	5	3.33	1.36	2.52	2	1.60	.70	1.15
April	4	13.68	6.32	11.18	4	3.10	1.14	2.09	3	.93	.49	.72
May	4	12.43	7.15	9.91	4	6.59	.67	2.68	2	.47	.40	.44
June	5	11.43	6.40	9.05	5	3.21	1.28	2.04	5	1.25	.30	.58
July	4	29.54	3.87	11.67	4	3.61	1.54	2.56	2	.80	.41	.61
August	5	36.58	3.73	13.16	5	3.14	1.03	1.65	5	.68	.30	.49
September	4	22.10	2.18	9.07	4	7.99	.08	2.41	4	.29	.01	.19
October	4	49.34	3.12	16.87	4	3.71	.41	1.96	2	.77	.21	.49
November	5	56.05	3.97	15.89	5	3.80	.67	1.64	5	1.05	.20	.46
December	3	12.81	5.77	8.96	3	1.33	.83	1.03	0	------	------	------

8a. 1971 summary of radioactivity in effluent waste water (Walnut Creek at Indiana Road) RFP, January-December 1971

Month (1971)	Uranium and plutonium					Plutonium					Americium				
	Number of samples	Concentration (pCi/liter)			Percent of AEC standards[a]	Number of samples	Concentration (pCi/liter)			Percent of AEC standards[b]	Number of samples	Concentration (pCi/liter)			Percent of AEC standards[c]
		Maximum	Minimum	Average			Maximum	Minimum	Average			Maximum	Minimum	Average	
January-June	24	30.06	2.85	11.41	------	24	8.47	0.67	2.64	------	16	1.67	0.30	0.79	------
July-December	25	56.05	2.18	12.90	------	25	7.99	0.41	1.89	------	18	1.05	0.01	0.43	------
Summary	[d] 49 (0)	56.05	2.18	12.17	0.23	[d] 49 (0)	8.47	0.41	2.26	0.14	[d] 34 (1)	1.67	0.01	0.60	0.05

[a] The standard for a mixture of soluble uranium and plutonium in water is $\frac{C_U}{MPC_U} + \frac{C_{Pu}}{MPC_{Pu}} \leq 1$ where MPC_U = 10 000 pCi/liter and MPC_{Pu} = 1 667 pCi/liter.

[b] Based on the soluble plutonium-239 in water standard of 1 667 pCi/liter.

[c] Based on the soluble americium-241 in water standard of 1 333 pCi/liter.

[d] ( ) denotes less than detectable levels.

Table 9. Radioactivity in reservoir water samples, Rocky Flats, January-December 1971

Location	Uranium and plutonium			Plutonium			Americium		
	Number of samples	Concentration (pCi/liter)		Number of samples	Concentration (pCi/liter)		Number of samples	Concentration (pCi/liter)	
		Maximum	Average		Maximum	Average		Maximum	Average
January-June 1971:									
Baseline Reservoir	12	6.06	3.25	[a] 11 (0)	1.68	0.33			
Great Western Reservoir	12	6.29	3.12	12 (2)	.64	.14	4	1.13	0.60
Ralston Reservoir	12	30.40	20.50	10 (9)	2.53	.26			
Standley Reservoir	11	17.44	5.23	10 (0)	4.93	.76	1	.10	.10
July-December 1971:									
Baseline Reservoir	8	6.92	3.29	8	.46	.13			
Great Western Reservoir	12	16.06	3.70	12	.82	.26	8	.49	.13
Ralston Reservoir	12	22.04	10.22	9	.96	.20			
Standley Reservoir	11	6.05	3.17	11	.24	.09	4	.12	.06

9a. 1971 summary of radioactivity in reservoir water samples, Rocky Flats

Reservoir	Uranium and plutonium					Plutonium					Americium			
	Number or samples	Number of samples less than detectable limit	Maximum (pCi/liter)	Average (pCi/liter)	Percent of AEC standard [b]	Number of samples	Number of samples less than detectable limit	Maximum (pCi/liter)	Average (pCi/liter)	Percent of AEC [c] standard	Number of samples	Maximum (pCi/liter)	Average (pCi/liter)	Percent of AEC standard [d]
Baseline	20	0	6.92	3.27	0.05	19	3	1.68	0.25	0.02				
Great Western	24	1	16.06	3.41	.04	24	3	.82	.20	.01	12	1.13	0.29	0.02
Ralston	24	0	30.40	15.36	.17	19	12	2.53	.23	.01				
Standley	22	0	17.44	4.20	.06	19	4	4.93	.39	.02	5	.12	.07	.01
Summary	90	1	30.40	6.76	0.08	81	22	4.93	0.26	0.02	17	1.13	0.22	0.02

[a] ( ) denotes number of samples less than detectable levels.

[b] The standard for a mixture of soluble uranium and plutonium in water is $\frac{C_U}{MPC_U}+\frac{C_{Pu}}{MPC_{Pu}} \leq 1$ where $MPC_U = 10\,000$ pCi/liter and $MPC_{Pu} = 1667$ pCi/liter.

[c] Based on the soluble plutonium-239 in water standard of 1 667 pCi/liter.

[d] Based on the soluble americium-241 in water standard of 1 333 pCi/liter.

to that time, samples were taken on a random basis and analyzed for gross alpha content. Although this gross alpha analysis would include plutonium and uranium as well as naturally occurring radionuclides, no specific plutonium analyses were routinely performed on these soil samples prior to that time.

The current program draws samples from a rough grid at 1, 2, and 5-mile distances from the center of the plant. About 75 locations, predominantly east and south of the plant site (corresponding to prevailing wind directions) but covering all areas between the perimeter and cattle fences, are sampled twice each year. In addition, locations along public right-of-way also are sampled, and samples are taken from Denver, Arvada, Westminster, between Boulder and Fort Collins, between Leyden and Golden, along 104th Avenue and in Coal Creek Canyon. All samples are to a depth of 1 centimeter. In all, 159 soil samples were collected in 1971 and analyzed specifically for plutonium.

No specific standard has been set for plutonium in soils. The levels obtained in this sampling program are shown in figure 5.

All evidence gathered to date by the Rocky Flats Health Physics Department and other official agencies indicate that the plant has made some contribution to plutonium soil concentrations in the immediate vicinity of the

Table 10. Radioactivity in community tap water samples, RFP, January-December 1971

Location	Uranium and plutonium				Plutonium			
	Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)		Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)	
			Maximum	Average			Maximum	Average
Community tap water samples, January–June:								
Arvada	12	0	16.20	7.64	9	7	0.77	0.10
Boulder	12	0	6.93	2.32	9	0	.97	.32
Broomfield	12	0	18.58	2.54	6	0	[a](5.03)	.98
Denver	12	0	17.19	5.73	11	2	2.79	.44
Golden	12	0	8.79	3.40	10	2	.45	.16
Lafayette	12	0	3.23	1.40	5	0	.77	.33
Louisville	12	0	2.45	1.25	4	0	.52	.28
Thornton	12	0	17.48	9.29	10	7	.30	.05
Westminster	12	0	6.49	2.26	11	1	1.80	.38
Radioactivity in reservoirs and tap water samples, July–December:								
Arvada	12	0	7.02	4.08	7	1	.78	.25
Boulder	12	0	8.62	1.66	10	5	.65	.17
Broomfield	12	0	9.00	2.84	9	3	.82	.25
Denver	12	0	5.77	2.89	9	3	2.03	.43
Golden	12	0	9.76	2.82	7	1	.47	.27
Lafayette	10	0	4.19	1.46	7	2	.82	.43
Louisville	11	0	3.15	1.31	7	1	1.60	.39
Thornton	11	0	8.60	4.88	6	1	.46	.21
Westminster	11	0	4.95	1.74	7	1	1.41	.43

10a. 1971 summary of radioactivity in community tap water samples, RFP

Location	Uranium and plutonium					Plutonium				
	Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)		Percent of AEC standard [b]	Number of samples	Number of samples less than detectable level	Concentration (pCi/liter)		Percent of AEC standard [c]
			Maximum	Average				Maximum	Average	
Arvada	24	0	16.20	5.86	0.07	16	8	0.78	0.16	0.01
Boulder	24	0	8.62	1.99	.03	19	5	.97	.24	.01
Broomfield	24	0	18.58	2.69	.05	15	3	[a](5.03)	.54	.03
Denver	24	0	17.19	4.31	.06	20	5	2.79	.44	.03
Golden	24	0	9.76	3.11	.04	17	3	.47	.20	.01
Lafayette	22	0	4.19	1.42	.03	12	2	.82	.39	.02
Louisville	23	0	3.15	1.27	.03	11	1	1.60	.35	.02
Thornton	23	0	17.48	7.18	.08	16	8	.46	.11	.01
Westminster	23	0	6.49	2.01	.04	18	2	1.80	.40	.02
Summary	211	0	18.58	3.32	0.04	144	37	(5.03)	0.31	0.01

[a] ( ) denotes suspect data.

[b] The standard for a mixture of soluble uranium+plutonium in water is $\frac{C_U}{MPC_U}+\frac{C_{Pu}}{MPC_{Pu}} \leq 1$ where MPC for uranium = 10 000 pCi/liter and MPC for plutonium = 1667 pCi/liter.

[c] The standard for soluble plutonium-239 in water is 1 667 pCi/liter.

Note: For averaging purposes, all samples below minimum detectable amounts (MDA) were assigned a fractional value (number of samples > MDA divided by total number of analyses) of the appropriate MDA.

site. There is, however, no evidence to indicate that there has been any measurable or significant contribution to the Greater Denver metro areas surrounding the plant. Nor is there any evidence that the levels found closer to the plant represent any health hazard.

Table 11. Semiannual water collection, RFP, 1971

Location	Concentration (pCi/liter)									
	Number of samples	Uranium + plutonium			Percent of standard [a]	Number of samples	Plutonium			Percent of standard [d]
		Minimum	Maximum	Average			Minimum	Maximum	Average	
<5 miles	28	0.54	16.35	2.72	0.05	13	0.05	2.76	0.41	0.02
>5 miles	32	.74	39.62	6.85	.08	16	.08	.92	.25	.01
Summary	60	0.55	39.62	4.92	0.07	29	0.05	2.76	0.32	0.02

[a] The standard for a soluble mixture of uranium + plutonium in water is $\frac{C_U}{MPC_U}+\frac{C_{Pu}}{MPC_{Pu}}\leq 1$ Where MPC for uranium is 10 000 pCi/liter and MPC for plutonium is 1 667 pCi/liter.

[b] The standard for soluble plutonium-239 in water is 1667 pCi/liter.

Table 12. Plutonium radioactivity in sediment samples[a] RFP, January-December 1971

Location	Concentration (pCi/g dry weight)		
	Number of samples	Maximum	Average
Pond A	4	26.06	17.53
Pond B-1	3	641.67	319.87
Pond B-2	3	385.53	199.00
Pond B-3	3	174.85	67.99
Pond B-4	3	181.34	65.68
Pond C	3	8.47	3.35
Baseline Reservoir	2	7.03	3.68
Great Western Reservoir	2	1.87	1.08
Ralston Reservoir	2	.65	.43
Standley Lake	2	.42	.29

[a] Sample is top 4 centimeters of sediment.

Note: For averaging purposes, all samples below minimum detectable amounts (MDA) were assigned a fractional value (number of samples >MDA divided by total number of analyses) of appropriate MDA.

Vegetation samples

Vegetation samples are collected from 75 locations within a radius of 20 miles from the plant site. These are taken from public right-of-way twice each year, and are confined to those plants normally consumed by grazing domestic animals. The various samples are analyzed specifically for plutonium.

Results for 1971 (table 13) show that plutonium levels were a maximum of 3.00 pCi/g (dry weight). One notable aspect of this sampling program is that the plant is analyzed without any prior washing. Thus, the plant becomes a form of dustfall collector as well as a measurement of the amount of plutonium physically incorporated into the plant through normal growth activities. Although no specific standard has been established for plutonium in or on plants, these levels are considered by most experts to be insignificant, especially in light of empirically derived dilution factors (*4*).

No specific routine analyses are performed at Rocky Flats on food or biological samples. Rocky Flats has contracted with the Radiobiology Department of Colorado State University to make ecological studies of the flora and fauna in the immediate environs of the plant. This will be a continuing project.

Summary and conclusions

The principal protection for our environment must be provided at the very source of potential degradation and/or potential pollution. No program can replace adequate controls at the source: any environmental program is after the fact.

This is especially true for radioactive isotopes. Rocky Flats is working toward total containment of radioactive materials. The data contained in this report are the result of the controls employed at this plant site and do not in any way describe those complex controls in themselves. That these controls are effective can be seen by comparing releases with those established standards over the applicable time periods.

Following a fire at Rocky Flats in May 1969, intensified soil and monitoring surveys disclosed some soil contamination in the vicinity of the plant site, primarily to the east of the perimeter fence. Subsequent investigations in-

Table 13. Plutonium radioactivity in vegetation samples, RFP environs, June and September 1971

Location	June 1971				September 1971			
	Number of samples	Number of samples less than detectable limit	Concentrations (pCi/g dry weight)		Number of samples	Number of samples less than detectable limit	Concentrations (pCi/g dry weight)	
			Maximum	Average[a]			Maximum	Average
<1 mile	20	5	2.5	0.29	22	8	3.0	0.18
1–5 miles	38	7	.79	.12	39	11	.39	.054
>5 miles	22	8	.25	.053	21	12	.17	.032
Summary	80	20	2.5	0.14	82	31	3.0	0.062

[a] For averaging purposes, all samples below minimum detectable amounts (MDA) were assigned a fractional value (number of samples >MDA divided by total number of analyses) of the appropriate MDA.

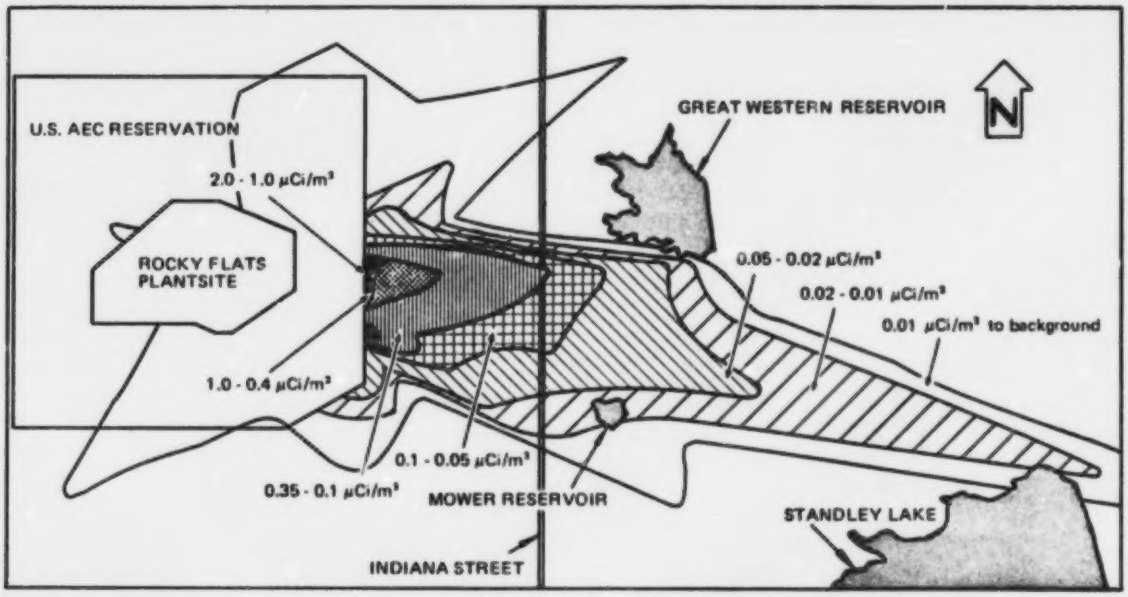
U.S. AEC RESERVATION
ROCKY FLATS PLANTSITE
2.0 - 1.0 µCi/m^2
1.0 - 0.4 µCi/m^2
0.35 - 0.1 µCi/m^2
0.1 - 0.05 µCi/m^2
MOWER RESERVOIR
INDIANA STREET
GREAT WESTERN RESERVOIR
N
0.05 - 0.02 µCi/m^2
0.02 - 0.01 µCi/m^2
0.01 µCi/m^2 to background
STANDLEY LAKE

Figure 5. Surface soil analysis, offsite contours (These contours were empirically derived by means of a computer curve-fitting program using the method of least squares. This results in a mathematical expression for grid sectors, giving the activity of plutonium in the soil as a function of radial distance from the onsite barrel storage area. Three hundred and forty-two soil samples were used in generating these contours. Eighteen samples were taken by the Colorado Committee on Environmental Information, 18 by U.S. AEC Health and Safety Laboratory, 306 by the Rocky Flats Health Physics Department. The values assume a soil density of 1 g/cm^3 at a depth of 1 centimeter.)

dicated that no measurable radioactive contamination had escaped from the buildings involved in that fire, and that the primary source of contamination had come from waste drums of contaminated oil stored near the east fence. Since it is felt that some resuspension of this material is inevitable, even though the most affected area is now covered with a thick asphalt pad, steps have been taken to reduce this possibility to an absolute minimum.

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The affected areas are under constant surveillance. The contours in figure 5 have been empirically derived using the best data available from all sources, i.e., the U.S. AEC Health and Safety Laboratory and the Colorado Committee for Environmental Information, as well as the surveillance activities of the Rocky Flats Health Physics Department.

Rocky Flats is committed to a soil sampling program. This program requires that samples be taken more frequently. Constant evaluation of the data thus generated shows no significant change in the contours.

Dustfall samples taken from the surrounding area may well represent some of this contaminated material that has been resuspended. Wind in the vicinity of Rocky Flats could deposit very small quantities of this material in the Boulder, Golden, Marshall, and Coal Creek areas. Dustfall sampling in these areas indicate that this may very well be the case. There are, however, other factors that might be creating anomalies as great as or even greater than any contribution from Rocky Flats. Wind currents, sweeping down through Boulder and Coal Creek Canyons, and along the Front Range, could be depositing greater than to be expected concentrations of materials associated with worldwide fallout in these areas. It must be emphasized that these concentrations, even including any contributions from Rocky Flats, are still on the same order of magnitude as that to be expected from worldwide fallout (*1*) and, as such, provide no known health and/or safety hazard to the public. There is probably a very real contribution from Rocky Flats. This contribution is so low as to provide no significant exposure risk to the population in the area. Ways of reducing this contribution are, however, under intensive study. Total plutonium releases during 1971 by both stack effluent discharge and effluent water release were a total of 1.0 millicuries (0.016 grams). Total uranium releases, which include relatively high concentrations of naturally occurring isotopes, were about 5 millicuries.

Plutonium stack effluent releases from Rocky Flats have, on a single sample or single-month-maximum basis, exceeded both recommended guidelines, and especially internal plant goals for limiting effluent concentrations. The same is true, although less frequently, for uranium releases. Although insignificant in terms of the yearly average concentrations, methods to limit and control those releases are being studied.

The primary reason for these higher-than-ordinary releases has been the system employed in changing filters in the exhaust plenums of process buildings. The time interval and the physical implementation of better techniques for these filter changes is under intensive study.

In summation, then, while Rocky Flats has met and mostly surpassed its goals for maintaining radioactive effluent emissions below the most restrictive standards available, to do even better is the implicit goal of the entire operation.

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Recent coverage in *Radiation Data and Reports:*

Period	*Issue*
1970	April 1973

2. Sandia Laboratories[3]
January–December 1971

Environmental Health Department[4]
Albuquerque, N. Mex.

Sandia Laboratories began as the Albuquerque branch of Los Alamos Scientific Laboratory after World War II and eventually became an independent engineering and research facility operated for the Atomic Energy Commission by the Bell System on a nonprofit basis. Although the laboratories are only a quarter-century old, they have already contributed significantly new capability and understanding in such areas as high temperature-resistant materials, microcircuitry and miniaturization, active ceramics, telemetry, high-speed photography, and environmental testing.

As part of the environmental testing capability, Sandia Laboratories operates two research nuclear reactors at the SPRF-SERF site in technical areas 3 and 5, (figure 6) located approximately 6 miles south of Albuquerque, N. Mex. Located on a mesa, the SPRF-SERF site is bounded topographically on the west by the Rio Grande, on the north by Tijeras Arroyo-Canyon, on the south by Hell's Canyon Wash, and on the east by the Manzano Mountains (figure 6).

The climate of the area is termed arid continental. Half the 8-inch average annual rainfall occurs during July to September, with the winter months being very dry. Temperature ranges are large, but extreme temperatures such as 0°F or 100°F are infrequent. Wind activity occurs mostly during the late winter and early spring months. On less than 13 percent of the days during the year does the maximum wind velocity reach 30 miles per hour.

The water table at the SPRF-SERF site is about 450 feet below the surface of the site. Indications are that ground water beneath the site moves from east to west towards the Rio Grande.

Sandia Laboratories, Albuquerque has conducted an environmental monitoring program since 1959 (*5*). The calendar year 1971 data are presented and discussed in this report.

Sample type and frequency

Soil and vegetation samples are collected annually at the 20 sites shown on figure 6. Vegetation samples are collected at the end of the growing season when plant uptake would be maximum. Deep well (approximately 1000 feet deep) water samples are collected quarterly from whichever of 8 portable water wells on Sandia base that are in use when the samples are taken (27 well water samples were taken in 1971).

All the above samples are analyzed for only gross beta, unless a high result is noted; in the event of such a high gross beta result, resampling is done and analyses are performed for strontium-90 and/or cesium-137.

Four additional soil sites, shown on figure 6, are sampled annually and the soil is analyzed for either gross alpha or total plutonium. These samples are for background data only, since Sandia Laboratories, Albuquerque currently handles plutonium only as sealed sources.

Sampling technique

Water—A 2-liter sample is taken in an acid-cleaned and distilled-water-rinsed plastic jug from the well head before any water treatment for human consumption.

Soil—Soil is collected from an area 1 foot square by 1 inch deep in a vegetation-free area and placed in a labelled plastic bag until analysis.

Vegetation—Available grass characteristic of the sampling site is collected in such a manner that no roots or soil contaminate the sample. The amount taken is about 500 grams and it is stored in plastic bags with air holes to prevent decomposition before analysis.

Methods of analysis

Water samples are shaken thoroughly when filtered, separating dissolved and suspended

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[3] Summarized from "Environmental Monitoring at Major U.S. Atomic Energy Commission, Sandia Laboratories, 1971."

[4] An AEC-owned facility operated for the U.S. Atomic Energy Commission by Sandia Corporation under Contract AT(29-1)-789.

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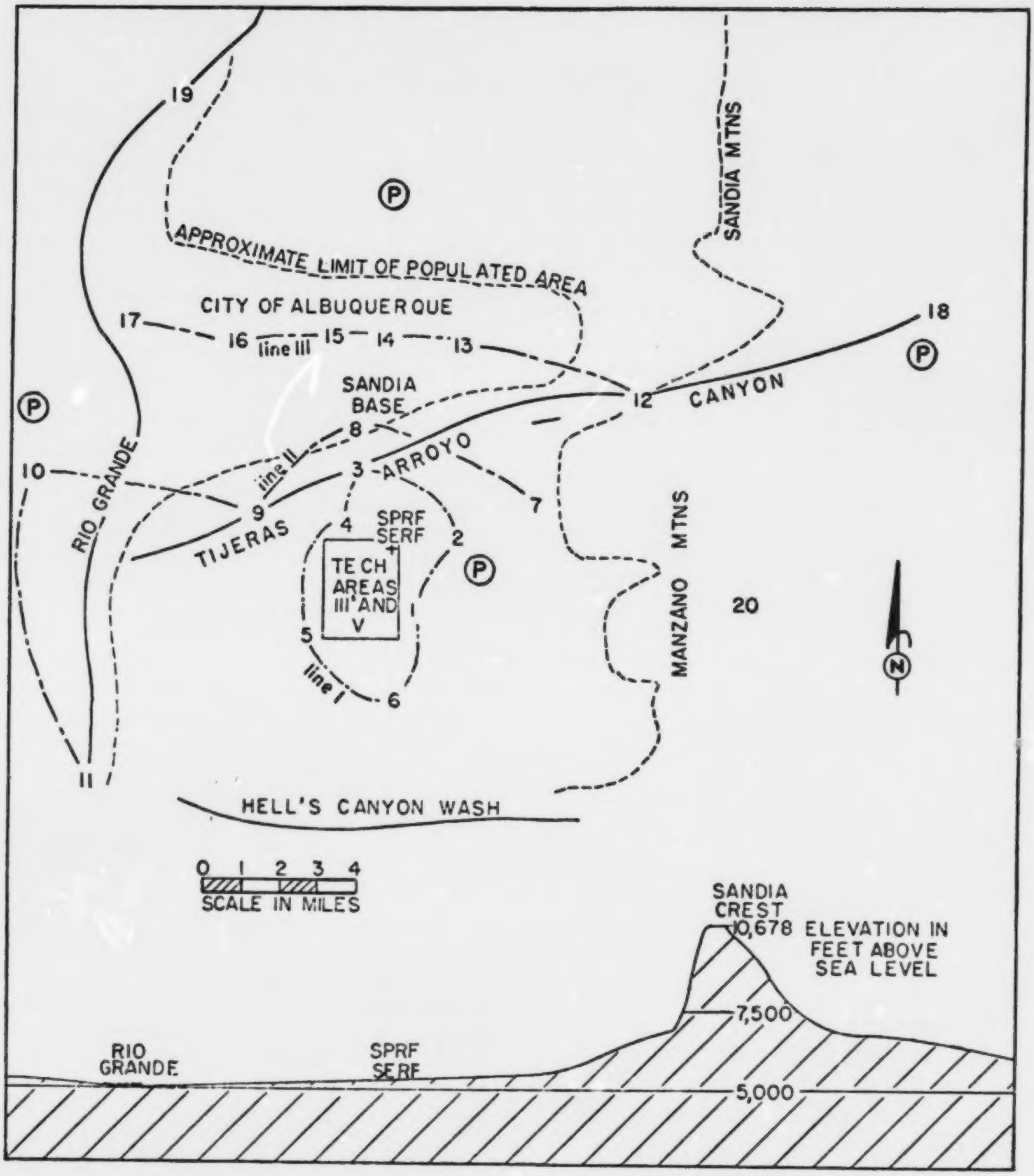
19
SANDIA MTNS
APPROXIMATE LIMIT OF POPULATED AREA
CITY OF ALBUQUERQUE
17
16
line III
15
14
13
18
12
CANYON
SANDIA BASE
8
line II
10
3
ARROYO
9
7
RIO GRANDE
TIJERAS
4
SPRF
SERF
2
TECH AREAS III AND V
MANZANO MTNS
20
N
5
line I
6
11
HELL'S CANYON WASH
0 1 2 3 4
SCALE IN MILES
SANDIA CREST
10,678 ELEVATION IN FEET ABOVE SEA LEVEL
7,500
5,000
RIO GRANDE
SPRF
SERF

Figure 6. Salient topography of Area 5 and site locations, Sandia Laboratories

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solids. Hardness of the water is determined so that no more than 7 mg/cm² of solids will be in the final deposit. Water is filtered through a hydrosol type membrane filter (0.45 μm). Filtered water is acidified with nitric acid and evaporated to a small volume which is transferred to a 2-inch tared stainless-steel planchet. The water then is evaporated to dryness, reweighed and beta counted.

The membrane filter is transferred to a 2-inch tared stainless-steel planchet, with solids down against planchet, the filter is dissolved in acetone, then excess acetone burned off. The planchet is reweighed and beta counted. The results of the water analyses are presented in table 14.

Table 14. Gross beta radioactivity in well water Sandia Laboratories, 1971

	Well water concentration (pCi/liter)
Dissolved solids (average)	2.81
Suspended solids (average)	.46
Total coverage	3.27
Most restrictive AEC standard	30
Percent of total gross beta in well water to standard	10.9

Water containing the cesium is passed through a KCFC[5] ion exchange column. The resin containing the cesium is gamma counted for cesium-137 (*6*).

Radiostrontium, calcium, barium, radium, and rare earth nuclides are precipitated from the water as oxalates. The calcium, barium, radium, and rare earth nuclides in the precipitate are separated as soluble nitrates from the strontium. The radiostrontium is allowed to sit for 15 days for the radioyttrium to grow in before counting (*7*).

Soil samples are mixed thoroughly, quartered if needed, then dried at 90°C overnight. The sample then is ground to pass a 200 mesh sieve. This fine powder is used for analysis.

Pretreated soil is reacted with HF to remove silica and then fused with sodium pyrosulfate. The fusion mixture is dissolved in HCl and diluted to a known volume with water. An aliquot is evaporated to dryness on a planchet and alpha counted.

The acid solution from the gross alpha determination is adjusted to 8*M* HCl. A tracer plutonium-236 is added and the plutonium is separated on an ion exchange resin. The plutonium is removed from the resin, electrodeposited and quantitated by alpha spectrometry (*8*).

Vegetation samples are mixed thoroughly, cut into small pieces (using a blender), ashed at 450°C, and the ash is used for analysis. Vegetation ash is treated with nitric acid to remove the beta activity, filtered, and the filtrate is planchetted for gross beta counting (*7*). The results of the soil and vegetation analyses are presented in table 15.

A 5 gram sample of pretreated soil or vegetation ash is fused with sodium carbonate. The fusion mixture is dissolved in water and acidified with nitric acid, and the cesium is collected on an ion exchange column (KCFC).[5] The resin containing the cesium is then gamma counted for cesium-137 (*8*).

To a 5 gram sample of pretreated soil or vegetation ash, barium and strontium carriers are added followed by concentrated nitric acid. The sample is digested and then evaporated to dryness. An oxalate precipitation followed by a nitrate precipitation of strontium is made. The strontium-90 is determined by allowing the yttrium to grow in for 15 days, and then the sample is beta counted (*7*).

Table 15. Gross beta radioactivity in soil and vegetation Sandia Laboratory, 1971

Sample sites [a]	Soil [b] (pCi/g dry weight)	Vegetation [c] (pCi/g ash weight)
1–6	[d]0.0 ± 2.9	171
7–11	2.8 ± 3.4	173
12–17	3.4 ± 3.4	139
18–20	1.9 ± 3.2	201

[a] See figure 6.
[b] All four samples analyzed for plutonium were below the detection limit of 3 pCi/g of dried soil.
[c] Vegetation was ashed at 450° C. before analysis. Ratio of wet weight to ash weight is about 12.
[d] Error limits are counting errors at the 95-percent confidence level.

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[5] KCFC, an inorganic ion exchange resin—potassium hexacyanocobalt (II) ferrate (II).

Summary

The environmental monitoring program conducted during 1971 showed that none of the samples of soil, vegetation, or well water taken near the nuclear reactor site in areas 3 and 5 contained radioactivity that was statistically different from the current background radioactivity in Albuquerque. We conclude that no health or environmental quality problem exists in Albuquerque as a result of any Sandia Laboratories facility operation.

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(*8*) BONI, A. L. Rapid ion exchange analysis of radiocesium in milk, urine, seawater and environmental samples. Anal Chem 38:89–92 (January 1966).

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3. Stanford Linear Accelerator Center[6] January–December 1971

Stanford Campus
San Mateo County, California

The Stanford Linear Accelerator Center (SLAC) is located 2 miles west of the Stanford Campus in San Mateo County, California. Its boundaries include Sand Hill Road on the north and San Francisquito Creek on the south. The land slopes to the south toward San Francisquito Creek. The total length of the accelerator and experimental areas is approximately 3 miles and is oriented almost east-west. Figure 7 shows SLAC with respect to the surrounding vicinity.

The SLAC regional surveillance program is intended to assess the contribution from SLAC operations, if any, to the existing radiation environment. Accordingly, samples of soil, vegetation, ground water, surface water, sanitary and storm sewers periodically are collected and activity levels determined. Continuous physical radiation measurements of neutron and gamma dose also is provided. Environmental and physical radiation monitoring locations are indicated in figure 8.

Environmental samples

There has been no evidence of increased radioactivity in environmental water, soil and vegetation samples collected and analyzed for gross beta and tritium activity during 1971. The level of radioactivity is comparable to preoperational levels and does not reflect any measurable change attributable to SLAC operations. Table 16 summarizes the gross beta activity found in environmental samples collected at SLAC. Tritium is not reported because all water samples contained less than the minimum detectable concentration of 3 nCi/liter.

During 1971, SLAC released 5.2 Ci of short-lived gases (^{15}O, ^{13}N, ^{11}C, and ^{41}Ar) to the atmosphere. This quantity represents <1 percent of the amount that could produce, beyond SLAC's boundaries, a concentration of 40 nCi/m^3 averaged over a 12-month period.

Table 16. Measured radioactivity in environmental samples Stanford Linear Accelerator Center, 1971

Sample type	Number of samples	Range of gross beta radioactivity results[a]
Well water (pCi/liter)	64	18–100
Surface water (pCi/liter)	4	1– 23
Stream silt as soil (pCi/g)	2	32– 36
Vegetation (pCi/g)	2	31– 36

[a] Includes potassium-40 radioactivity.

Table 17. Annual dose measured at peripheral monitoring stations, Stanford Linear Accelerator Center, 1971

Station	Gamma and neutron[a] dose (mrem)
1	110 (104)
2	81 (88)
3	80 (68)
4	92 (70)
5	115 (100)
6	82 (100)
8	90 (86)

[a] Value includes background radiation, number in parenthesis indicate annual background measurement at each station from 1968 data.

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[6] Summarized from "Environmental Montoring at Major U.S. Atomic Energy Commission, Stanford Linear Acceleration Center, 1971."

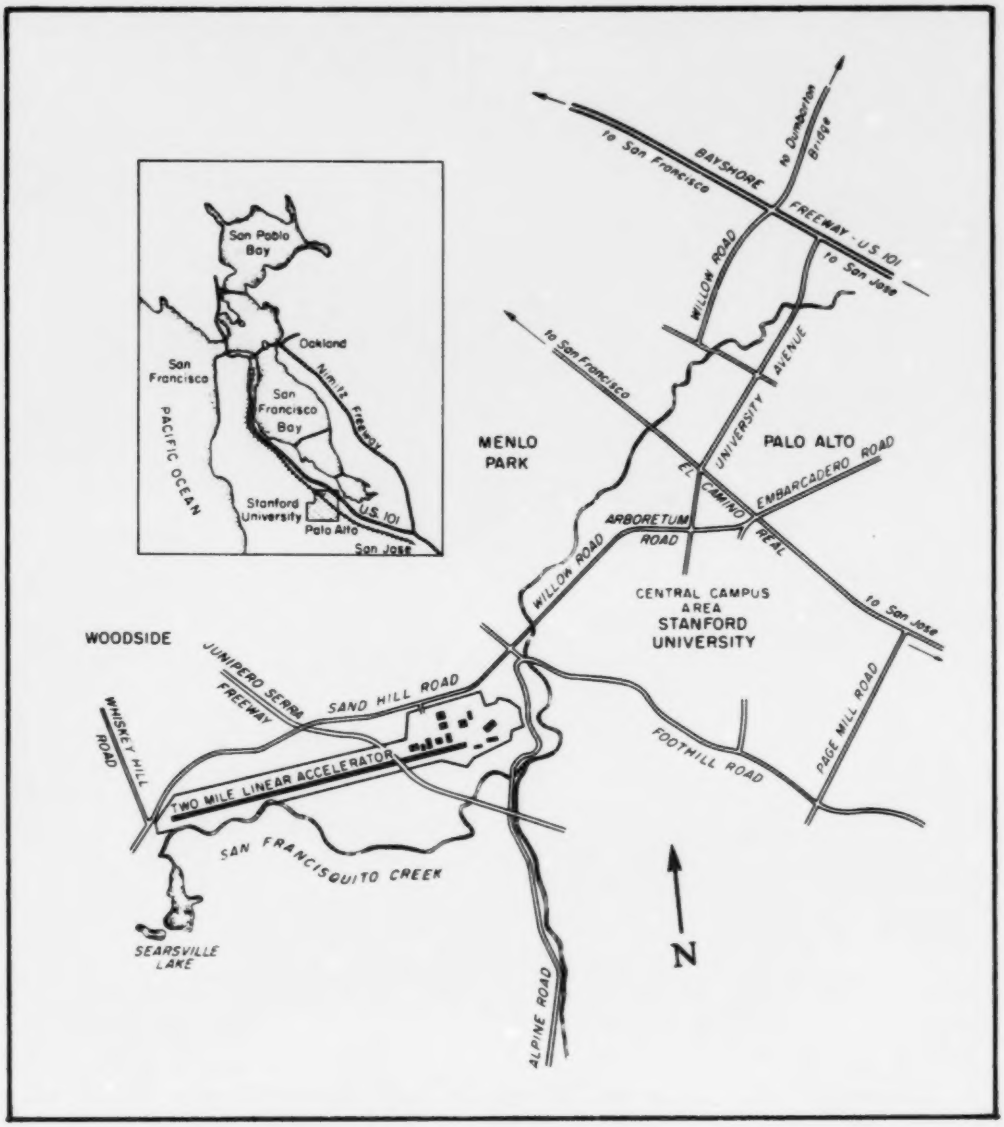
to San Francisco
BAYSHORE FREEWAY - US 101
to Dumbarton Bridge
to San Jose
WILLOW ROAD
UNIVERSITY AVENUE
to San Francisco
MENLO PARK
PALO ALTO
EL CAMINO REAL
EMBARCADERO ROAD
ARBORETUM ROAD
WILLOW ROAD
CENTRAL CAMPUS AREA
STANFORD UNIVERSITY
to San Jose
WOODSIDE
JUNIPERO SERRA FREEWAY
SAND HILL ROAD
WHISKEY HILL ROAD
TWO MILE LINEAR ACCELERATOR
FOOTHILL ROAD
PAGE MILL ROAD
SAN FRANCISQUITO CREEK
SEARSVILLE LAKE
ALPINE ROAD
N
San Pablo Bay
Oakland
San Francisco
Nimitz Freeway
San Francisco Bay
PACIFIC OCEAN
Stanford University
US 101
Palo Alto
San Jose

Figure 7. Site location relative to Stanford University and surrounding communities

Radiation measurements

Physical radiation measurements, near SLAC's boundaries, which include gamma and neutron radiation levels caused by skyshine, are summarized in table 17 and include background radiation response. Preoperational measurements of background radiation at SLAC and measurements made during periods when the accelerator was not operating indicate a total annual dose of 110 ± 20 mrem averaged over the seven operation stations.

From these measurements it can be concluded that, only one station recorded a small increase over background which is <5 percent of the permissible annual individual dose at the site boundary.

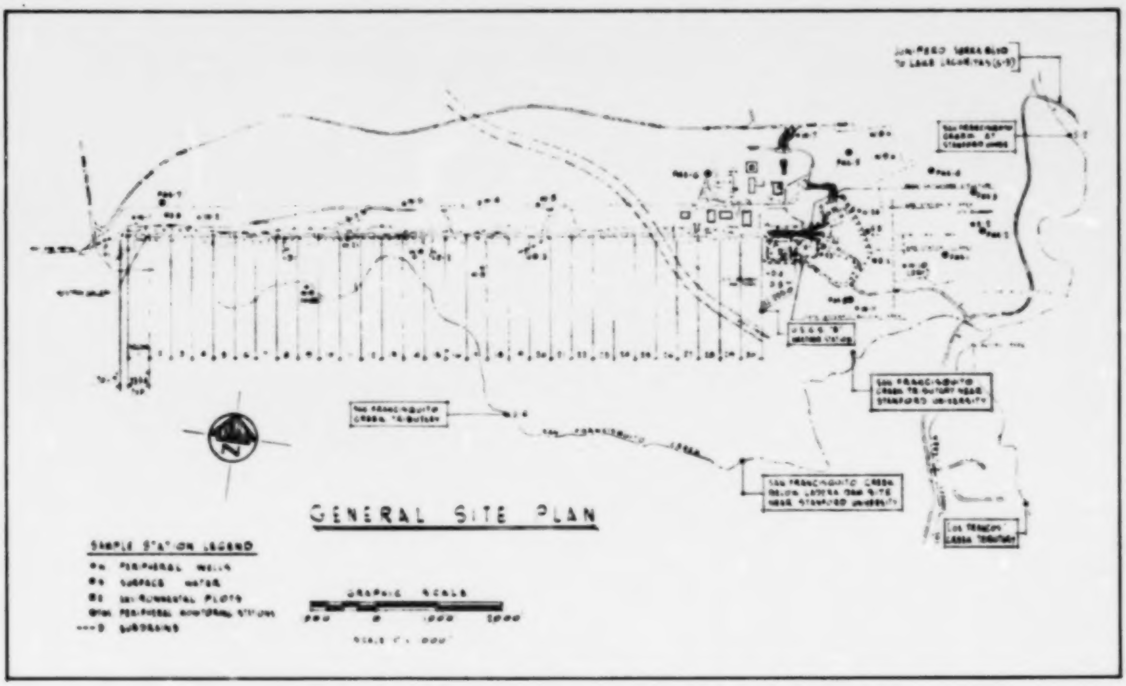
JUNIPERO SERRA BLVD TO LAKE LAGUNITAS (S-9)
SAN FRANCISQUITO CREEK AT STANFORD LANDS
U.S.G.S. WEATHER STATION
SAN FRANCISQUITO CREEK TRIBUTARY
SAN FRANCISQUITO CREEK TRIBUTARY NEAR STANFORD UNIVERSITY
SAN FRANCISQUITO CREEK BELOW LADERA DAM SITE NEAR STANFORD UNIVERSITY
LOS TRANCOS CREEK TRIBUTARY
N
GENERAL SITE PLAN
SAMPLE STATION LEGEND
PERIPHERAL WELLS
SURFACE WATER
ENVIRONMENTAL PLOTS
PERIPHERAL MONITORING STATIONS
SUBDRAINS
GRAPHIC SCALE
500
0
1000
2000

Figure 8. Environmental and physical radiation monitoring locations Stanford Linear Accelerator Center

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Nuclear Power Reactors in the United States
March 31, 1974

Each quarter year, the Atomic Energy Commission releases information on the status of all present and proposed civilian nuclear power generating units in the United States. This information is reproduced for interested readers of *Radiation Data and Reports*.

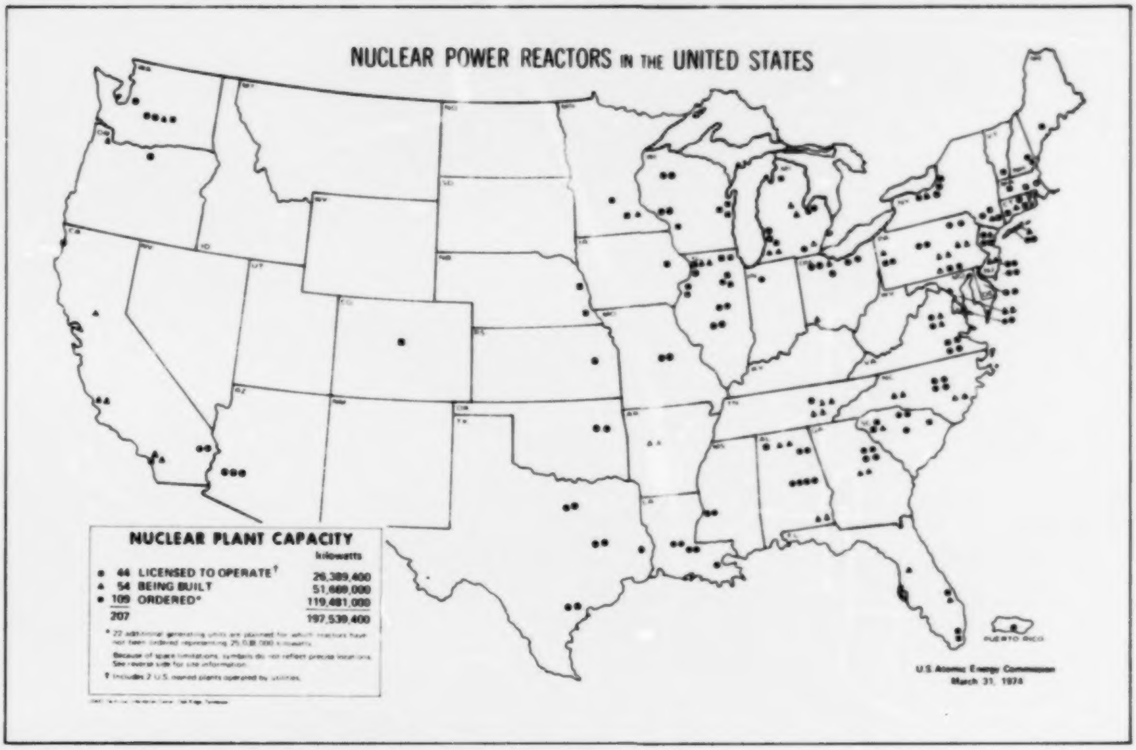
NUCLEAR POWER REACTORS IN THE UNITED STATES
NUCLEAR PLANT CAPACITY
kilowatts
● 44 LICENSED TO OPERATE† 26,389,400
▲ 54 BEING BUILT 51,669,000
● 109 ORDERED* 119,481,000
207 197,539,400
Because of space limitations, symbols do not reflect precise locations. See reverse side for site information.
† Includes 2 U.S. owned plants operated by utilities.
PUERTO RICO
U.S. Atomic Energy Commission
March 31, 1974

Figure 1. Nuclear power reactors in the United States, March 31, 1974

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SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,065,000	Tennessee Valley Authority	1973
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,065,000	Tennessee Valley Authority	1974
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,065,000	Tennessee Valley Authority	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 1	829,000	Alabama Power Co.	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 2	829,000	Alabama Power Co.	1977
Chilton County	Central Alabama Nuclear Plant: Unit 1	1,200,000	Alabama Power Co.	1982
Chilton County	Central Alabama Nuclear Plant: Unit 2	1,200,000	Alabama Power Co.	1983
Elmore County	Central Alabama Nuclear Plant: Unit 3	1,200,000	Alabama Power Co.	1984
Elmore County	Central Alabama Nuclear Plant: Unit 4	1,200,000	Alabama Power Co.	1985
Scottsboro	Bellefonte Nuclear Plant: Unit 1	1,189,000	Tennessee Valley Authority	1979
Scottsboro	Bellefonte Nuclear Plant: Unit 2	1,189,000	Tennessee Valley Authority	1980
ARIZONA				
Wintersburg	Palo Verde Nuclear Generation Station: Unit 1	1,270,000	Arizona Public Service	1981
Wintersburg	Palo Verde Nuclear Generating Station: Unit 2	1,270,000	Arizona Public Service	1982
Wintersburg	Palo Verde Nuclear Generating Station: Unit 3	1,270,000	Arizona Public Service	1984
ARKANSAS				
Russellville	Arkansas Nuclear One: Unit 1	850,000	Arkansas Power & Light Co.	1974
Russellville	Arkansas Nuclear One: Unit 2	912,000	Arkansas Power & Light Co.	1976
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	65,000	Pacific Gas and Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1968
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1979
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1980
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,084,000	Pacific Gas and Electric Co.	1975
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,106,000	Pacific Gas and Electric Co.	1976
Clay Station	Rancho Seco Nuclear Generating Station	913,000	Sacramento Municipal Utility District	1974
*	—	1,128,000	Pacific Gas & Electric Co.	1981
*	—	1,128,000	Pacific Gas & Electric Co.	1982
Vidal	Vidal Generating Station: Unit 1	770,000	Southern California Edison Co.	1981
Vidal	Vidal Generation Station: Unit 2	770,000	Southern California Edison Co.	1982
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1974
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1968
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1971
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
Waterford	Millstone Nuclear Power Station: Unit 3	1,150,000	Northeast Utilities	1979
DELAWARE				
Summit	Summit Power Station: Unit 1	770,000	Delmarva Power & Light Co.	1980
Summit	Summit Power Station: Unit 2	770,000	Delmarva Power & Light Co.	1982
FLORIDA				
Florida City	Turkey Point Station: Unit 3	693,000	Florida Power & Light Co.	1972
Florida City	Turkey Point Station: Unit 4	693,000	Florida Power & Light Co.	1973
Red Level	Crystal River Plant: Unit 3	825,000	Florida Power Corp.	1974
Ft. Pierce	St. Lucie Plant: Unit 1	801,000	Florida Power & Light Co.	1975
Ft. Pierce	St. Lucie Plant: Unit 2	801,000	Florida Power & Light Co.	1979
*	—	1,300,000	Florida Power Corp.	1983
*	—	1,300,000	Florida Power Corp.	1986
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1974
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	795,000	Georgia Power Co.	1978
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 1	1,121,000	Georgia Power Co.	1980
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 2	1,121,000	Georgia Power Co.	1981
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 3	1,121,000	Georgia Power Co.	1982
Waynesboro	Alvin W. Vogtle, Jr. Plant: Unit 4	1,121,000	Georgia Power Co.	1983
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	809,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	809,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1973
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1974
Cordova	Quad-Cities Station: Unit 1	800,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Cordova	Quad-Cities Station: Unit 2	800,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Seneca	LaSalle County Nuclear Station: Unit 1	1,078,000	Comm. Ed. Co.-Ia.	1978
Seneca	LaSalle County Nuclear Station: Unit 2	1,075,000	Comm. Ed. Co.-Ia.	1979
Bryon	Byron Station: Unit 1	1,120,000	Comm. Edison Co.	1980
Bryon	Byron Station: Unit 2	1,120,000	Comm. Edison Co.	1981
Bradwood	Bradwood: Unit 1	1,200,000	Comm. Edison Co.	1980
Bradwood	Bradwood: Unit 2	1,200,000	Comm. Edison Co.	1981
Clinton	Clinton Nuclear Power Plant: Unit 1	955,000	Illinois Power Co.	1980
Clinton	Clinton Nuclear Power Plant: Unit 2	955,000	Illinois Power Co.	1982
INDIANA				
Porter County	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1979
IOWA				
Palo	Duane Arnold Energy Center: Unit 1	569,000	Iowa Electric Light and Power Co.	1974
KANSAS				
Burlington	Wolf Creek Generation Station: Unit 1	1,150,000	Kansas Gas & Electric–Kansas City P & L	1981
LOUISIANA				
Taft	Waterford Generating Station	1,113,000	Louisiana Power & Light Co.	1977
St. Francisville	River Bend Station: Unit 1	934,000	Gulf States Utilities Co.	1980
St. Francisville	River Bend Station: Unit 2	934,000	Gulf States Utilities Co.	1981
St. Rosalie	—	1,200,000	Louisiana Power & Light Co.	1982
St. Rosalie	—	1,200,000	Louisiana Power & Light Co.	1984

Figure 1. Nuclear power reactors in the United States, March 31, 1974—continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1974
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1975
Nanjemoy	Douglas Point Project: Unit 1	1,178,000	Potomac Electric Power Co.	1980
Nanjemoy	Douglas Point Project: Unit 2	1,178,000	Potomac Electric Power Co.	1981
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station: Unit 1	664,000	Boston Edison Co.	1972
Plymouth	Pilgrim Station: Unit 2	1,180,000	Boston Edison Co.	1980
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	75,000	Consumers Power Co.	1965
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1971
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1976
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 3	1,172,000	Detroit Edison Co.	1981
Bridgman	Donald C. Cook Plant: Unit 1	1,060,000	Indiana & Michigan Electric Co.	1974
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1976
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1980
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1979
St. Clair County	Greenwood: Unit 2	1,200,000	Detroit Edison Co.	1980
St. Clair County	Greenwood: Unit 3	1,200,000	Detroit Edison Co.	1981
Quanicassee	Quanicassee: Unit 1	1,150,000	Consumers Power Co.	1981
Quanicassee	Quanicassee: Unit 2	1,150,000	Consumers Power Co.	1982
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1971
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1973
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
MISSOURI				
Fulton	Calloway Plant: Unit 1	1,150,000	Union Electric Co.	1981
Fulton	Calloway Plant: Unit 2	1,150,000	Union Electric Co.	1983
MISSISSIPPI				
Port Gibson	Grand Gulf Nuclear Station: Unit 1	1,290,000	Mississippi Power & Light Co.	1979
Port Gibson	Grand Gulf Nuclear Station: Unit 2	1,290,000	Mississippi Power & Light Co.	1981
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1973
Brownville	Cooper Nuclear Station	778,000	Nebraska Public Power District and Iowa Power and Light Co.	1974
NEW HAMPSHIRE				
Seabrook	Seabrook Nuclear Station: Unit 1	1,200,000	Public Service of N.H.	1979
Seabrook	Seabrook Nuclear Station: Unit 2	1,200,000	Public Service of N.H.	1981
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	640,000	Jersey Central Power & Light Co.	1969
Forked River	Forked River Generating Station: Unit 1	1,070,000	Jersey Central Power & Light Co.	1979
Salem	Salem Nuclear Generating Station: Unit 1	1,090,000	Public Service Electric and Gas, N.J.	1975
Salem	Salem Nuclear Generating Station: Unit 2	1,115,000	Public Service Electric and Gas, N.J.	1976
Salem	Hope Creek Generating Station: Unit 1	1,067,000	Public Service Electric and Gas, N.J.	1981
Salem	Hope Creek Generating Station: Unit 2	1,067,000	Public Service Electric and Gas, N.J.	1982
Little Egg Inlet	Atlantic Generating Station: Unit 1	1,150,000	Public Service Electric and Gas, N.J.	1980
Little Egg Inlet	Atlantic Generating Station: Unit 2	1,150,000	Public Service Electric and Gas, N.J.	1981
•	–	1,150,000	Public Service Electric and Gas, N.J.	1983
•	–	1,150,000	Public Service Electric and Gas, N.J.	1984
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1962
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1973
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1974
Scriba	Nine Mile Point Nuclear Station: Unit 1	625,000	Niagara Mohawk Power Co.	1969
Scriba	Nine Mile Point Nuclear Station: Unit 2	1,080,000	Niagara Mohawk Power Co.	1978
Ontario	R. E. Ginna Nuclear Power Plant: Unit 1	490,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N.Y.	1973
Jamesport	–	1,150,000	Long Island Lighting Co.	1981
Jamesport	–	1,150,000	Long Island Lighting Co.	1983
Oswego	Sterling Nuclear: Unit 1	1,150,000	Rochester Gas & Electric Co.	1982
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1975
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1974
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,180,000	Duke Power Co.	1976
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,180,000	Duke Power Co.	1977
Bonsal	Shearon Harris Plant: Unit 1	915,000	Carolina Power & Light Co.	1978
Bonsal	Shearon Harris Plant: Unit 2	915,000	Carolina Power & Light Co.	1979
Bonsal	Shearon Harris Plant: Unit 3	915,000	Carolina Power & Light Co.	1980
Bonsal	Shearon Harris Plant: Unit 4	915,000	Carolina Power & Light Co.	1981
Davie County	Perkins Nuclear Station: Unit 1	1,280,000	Duke Power Co.	1981
Davie County	Perkins Nuclear Station: Unit 2	1,280,000	Duke Power Co.	1982
Davie County	Perkins Nuclear Station: Unit 3	1,280,000	Duke Power Co.	1982
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station: Unit 1	906,000	Toledo Edison-Cleveland El. Illum. Co.	1976
Oak Harbor	Davis-Besse Nuclear Power Station: Unit 2	906,000	Toledo Edison-Cleveland El. Illum. Co.	1981
Oak Harbor	Davis-Besse Nuclear Power Station: Unit 3	906,000	Toledo Edison-Cleveland El. Illum. Co.	1983
Perry	Perry Nuclear Power Plant: Unit 1	1,205,000	Cleveland Electric Illuminating Co.	1979
Perry	Perry Nuclear Power Plant: Unit 2	1,205,000	Cleveland Electric Illuminating Co.	1980
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1977
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 2	1,170,000	Cincinnati Gas & Electric Co.	1982

Figure 1. Nuclear power reactors in the United States, March 31, 1974—continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	COMMERCIAL OPERATION
OKLAHOMA				
Inola	Black Fox Nuclear Station: Unit 1	950,000	Public Service of Oklahoma	1982
Inola	Black Fox Nuclear Station: Unit 2	950,000	Public Service of Oklahoma	1984
OREGON				
Prescott	Trojan Nuclear Plant: Unit 1	1,130,000	Portland General Electric Co.	1975
Boardman	Boardman I	1,200,000	Portland General Electric Co.	1980
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1974
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1974
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1979
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1980
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	852,000	Duquesne Light Co.-Ohio Edison Co.	1975
Shippingport	Beaver Valley Power Station: Unit 2	852,000	Duquesne Light Co.-Ohio Edison Co.	1979
Goldsboro	Three Mile Island Nuclear Station: Unit 1	819,000	Metropolitan Edison Co.	1974
Goldsboro	Three Mile Island Nuclear Station: Unit 2	905,000	Jersey Central Power & Light Co.	1976
Berwick	Susquehanna Steam Electric Station: Unit 1	1,050,000	Pennsylvania Power and Light	1979
Berwick	Susquehanna Steam Electric Station: Unit 2	1,050,000	Pennsylvania Power and Light	1981
Fuller	Fulton Generating Station: Unit 1	1,140,000	Philadelphia Electric Co.	1981
Fuller	Fulton Generating Station: Unit 2	1,140,000	Philadelphia Electric Co.	1983
SOUTH CAROLINA				
Hartsville	H. B. Robinson S.E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1971
Seneca	Oconee Nuclear Station: Unit 1	886,000	Duke Power Co.	1973
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1973
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1974
Broad River	Virgil C. Summer Nuclear Station: Unit 1	900,000	South Carolina Electric & Gas Co.	1978
Lake Wylie	Catawba Nuclear Station: Unit 1	1,153,000	Duke Power Co.	1979
Lake Wylie	Catawba Nuclear Station: Unit 2	1,153,000	Duke Power Co.	1980
Cherokee County	Cherokee Nuclear Station: Unit 1	1,280,000	Duke Power Co.	1982
Cherokee County	Cherokee Nuclear Station: Unit 2	1,280,000	Duke Power Co.	1983
Cherokee County	Cherokee Nuclear Station: Unit 3	1,280,000	Duke Power Co.	1984
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,140,000	Tennessee Valley Authority	1975
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,140,000	Tennessee Valley Authority	1976
Spring City	Watts Bar Nuclear Plant: Unit 1	1,169,000	Tennessee Valley Authority	1978
Spring City	Watts Bar Nuclear Plant: Unit 2	1,169,000	Tennessee Valley Authority	1978
Oak Ridge	Clinch River Breeder Reactor Plant	350,000	U.S. Government	1980
TEXAS				
Glen Rose	Commanche Peak Steam Electric Station: Unit 1	1,150,000	Texas Utilities Services Inc.	1980
Glen Rose	Commanche Peak Steam Electric Station: Unit 2	1,150,000	Texas Utilities Services Inc.	1982
Jasper	Blue Hills: Unit 1	918,000	Gulf States Utilities	1980
Wallis	Allens Creek: Unit 1	1,150,000	Houston Lighting & Power Co.	1980
Wallis	Allens Creek: Unit 2	1,150,000	Houston Lighting & Power Co.	1982
Matagorda County	South Texas Project	1,250,000	Central Power & Light Co.	1980
Matagorda County	South Texas Project	1,250,000	Central Power & Light Co.	1982
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.	1972
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	788,000	Virginia Electric & Power Co.	1972
Gravel Neck	Surry Power Station: Unit 2	788,000	Virginia Electric & Power Co.	1973
Mineral	North Anna Power Station: Unit 1	898,000	Virginia Electric & Power Co.	1975
Mineral	North Anna Power Station: Unit 2	898,000	Virginia Electric & Power Co.	1976
Mineral	North Anna Power Station: Unit 3	907,000	Virginia Electric & Power Co.	1977
Mineral	North Anna Power Station: Unit 4	907,000	Virginia Electric & Power Co.	1978
Gravel Neck	Surry Power Station: Unit 3	882,000	Virginia Electric & Power Company	1980
Gravel Neck	Surry Power Station: Unit 4	882,000	Virginia Electric & Power Company	1981
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	850,000	Atomic Energy Commission	1966
Richland	WPPSS No. 1	1,206,000	Washington Public Power Supply System	1980
Richland	WPPSS No. 2	1,103,000	Washington Public Power Supply System	1977
Satsop	WPPSS No. 3	1,242,000	Washington Public Power Supply System	1981
Sedro Woolley	Skagit Nuclear Project	1,200,000	Puget Sound Power & Light	1982
WISCONSIN				
Genoa	Genoa Nuclear Generating Station	50,000	Dairyland Power Cooperative	1971
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1972
Carlton	Kewaunee Nuclear Power Plant: Unit 1	541,000	Wisconsin Michigan Power Co.	1973
*	–	900,000	Wisconsin Electric Power Co.	1980
*	–	900,000	Wisconsin Electric Power Co.	1982
Durand	Tyrone Energy Park: Unit 1	1,150,000	Northern States Power Co.	1982
Durand	Tyrone Energy Park: Unit 2	1,150,000	Northern States Power Co.	1983
PUERTO RICO				
Puerto De Jobas	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1979
*	–	1,228,000	Tennessee Valley Authority	1980
*	–	1,228,000	Tennessee Valley Authority	1981
*	–	1,228,000	Tennessee Valley Authority	1980
*	–	1,228,000	Tennessee Valley Authority	1981

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* Site not selected.

Figure 1. Nuclear power reactors in the United States, March 31, 1974—continued

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Reported Nuclear Detonations, April 1974

(Includes seismic signals presumably from foreign nuclear detonations)

There were no reported nuclear detonations for the United States for April 1974 and no recorded seismic signals for this month.

Information in this section is based on data received during the month, and is subject to change as additional information may become available. Persons requiring information for purposes of compiling announced nuclear detonation statistics are advised to contact the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL AND RADIOLOGICAL MONITORING AT THE NATIONAL REACTOR TESTING STATION DURING FY-1973 (July 1972–June 1973).

O. Doyle Markham. Radiation Data and Reports, Vol. 15, May 1974, pp. 227–246

The routine environmental monitoring program at the National Reactor Testing Station (NRTS) during FY-1973 is described. In addition to the measurement of direct radiation exposures in the environment, the concentrations of radioactivity in air, groundwater, and milk also are determined. The results of the soil sampling program are discussed. The data from onsite and nearby community sampling locations are compared to background concentrations and the applicable standards established by the U.S. Atomic Energy Commission.

In addition, several special ecological monitoring programs have been designed to assess the effect of NRTS operations on the environment. One of the ecological studies quantifies the level of radioactivity in antelope tissues collected on and near the NRTS. An investigation to ascertain the ratio of iodine-129 to stable iodine-127 in the NRTS environs also is described.

KEYWORDS: air, antelope, ecological studies, groundwater, iodine, milk, National Reactor Testing Station, soil.

PERSONNEL AND ENVIRONMENTAL THERMOLUMINESCENT DOSIMETRY FOR A UNIVERSITY REACTOR LOCATED IN A SEMITROPICAL AREA.

P. S. Weng and C. Y. Huan. Radiation Data and Reports. Vol. 15, May 1974, pp. 247–252

The ^{7}LiF-Teflon discs were added to the film badges for personnel monitoring during a 6-month period. The results showed a consistently higher dose in the thermoluminescent dosimeter than in the photographic film dosimeter, which might exhibit about 90 percent fading during the 4-week monitoring period in a hot and humid climate. In winter time it was found that the response from both LiF-Teflon disc and film showed more consistent results due to better climate conditions in Taiwan. The CaSO$_4$:Dy and CaSO$_4$:Tm phosphor powders and LiF:Mg, Ti, enclosed in a knot of bamboo stick, were used for environmental monitoring at a university reactor site and inside a research reactor building. The results showed that they were unaffected by extremes of humidity and environmental temperatures in area monitoring, either indoors or outdoors.

KEYWORDS: Film badge, reactor, Taiwan, thermoluminescent dosimeter.

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RADIATION DATA AND REPORTS

Volume 15, Number 6, June 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

- Department of Defense
- Department of Agriculture
- Department of Commerce
- Department of Health, Education, and Welfare
- Environmental Protection Agency
- Atomic Energy Commission

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Russell E. Train, Administrator

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Calculations of Dose, Population Dose and Health Effects Due To Boiling Water Nuclear Power Reactor Radionuclide Emissions In The United States During 1971 [1]

J. A. Martin, Jr. and C. B. Nelson [2]

Atmospheric emissions of radionuclides during 1971 reported by operators of 10 boiling water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A recently developed computer program (AIREM) was used to perform the calculations. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 80 kilometers. In 1971, 3.2 million curies of radioactivity were released to the atmosphere from 10 reactors. The resulting whole body population dose was calculated to be 900 person-rem. The health effects associated with this population dose were calculated to be small fractions of those induced by natural background radiation.

The Office of Radiation Programs (ORP) is analyzing reported airborne emissions of radionuclides from operating boiling water nuclear power reactors to calculate doses [3] to populations within 80 km (50 miles) of the emission points. This report summarizes calculated doses due to radionuclides emitted by such facilities during 1971. Doses were calculated using the AIREM (*1*) computer code recently developed for this purpose by the Surveillance Branch, ORP. This code diffuses the radionuclides according to a standard long-term, sector-averaged equation (*2*) and includes ground and inversion lid reflections, radionuclide decay by time-of-flight, ground deposition and cloud depletion, first daughter product in-growth and decay, and contributions to dose from radionuclides in clouds at all azimuths. Whole body doses due to the gamma rays emitted within the cloud (cloud gamma doses) were calculated using a model that considers the finite extent of the cloud, all decay gamma energies, and dose buildup factors. The finite cloud model used is a modified version of R. E. Cooper's EGAD code (*3*). For doses other than cloud gamma doses, dose rate conversion factors (rem/year per Ci/m^3) were obtained using techniques suggested in references *4* and *5*. Gamma and beta intensity data were obtained from reference *6*. Plume rise was calculated according to the methods of Briggs (*7*). The geometry of the AIREM code is as illustrated in figure 1. Ground level doses are calculated for each sector-segment. The populations within sector-segments are assumed to exist full time at the points (denoted by X's) where doses are calculated. Incremental population dose is the product of the population in a sector-segment and the dose in that sector-segment. Total population dose is the sum of all the incremental population doses. Average dose to the population is the total population dose divided by the total population. Health effects were calculated using a risk factor of 7 × 10^{-4} health effects per person-rem (*4*).

A large body of data was accumulated and used in the calculations. Stack dimensions and exit gas parameters (e.g., flow rate, tempera-

---

[1] This article is based on a paper that was presented at the International Atomic Energy Agency/World Meteorological Organization Symposium on the Physical Behavior of Radionuclides Released to the Atmosphere, Vienna, Austria (November 1973).

[2] Field Operations Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460.

[3] Corresponding to common practice, dose = dose equivalent in this report.

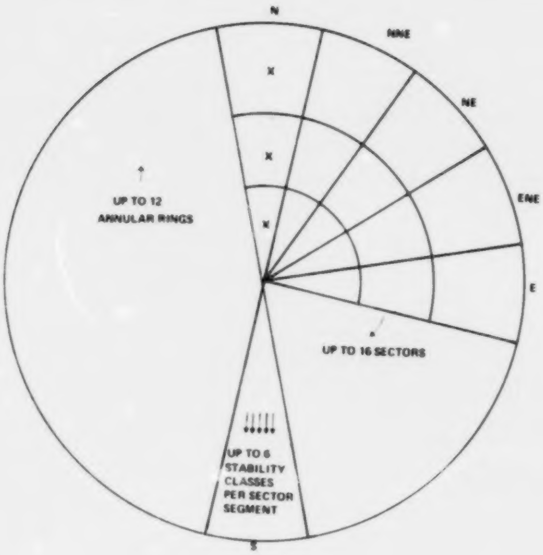

Figure 1. Geometry of AIREM

ture) were obtained from facility operators, as were plot plans of the facilities. Source terms (activity of each radionuclide released) were obtained from published AEC data (*8*) or from the AEC directly when the published data did not detail the release by radionuclide. Wind frequency and wind speed distributions used in the calculations were facility-provided annual averages; these were all obtained from onsite meteorological instrumentation. Cloud diffusion parameters used were those suggested by the EPA Office of Air Programs (*2*). Annual average height of the mixing layer was obtained from reference *9*.

The 1970 census data were used to determine population distributions. Where deposition was calculated (i.e., for the iodines and particulate daughter products), a deposition velocity of 1 centimeter per second was assumed. Most facility-provided data have been reported in either their safety analysis or environmental reports; however, in several cases, the facility provided as yet unpublished data through the EPA Regional Radiation Representatives.

Code comparisons

A complete description of the calculations performed for the subject facilities is beyond the scope of this report; such will appear in the code program manual presently being written (*1*). Two examples are presented here, however, to illustrate some significant comparisons to common experience.

Finite cloud vs. semi-infinite cloud doses

The assumption of a semi-infinite cloud has often been used (*4,5*) to calculate cloud gamma dose. The differences between doses calculated using AIREM with the modified EGAD finite cloud model and doses calculated using the semi-infinite cloud model are displayed in figure 2. The same sector-averaged diffusion equation (*2*) was used in both cases. As expected, the difference is small at large distances from the release point since by then the cloud has expanded considerably and the semi-infinite cloud assumption is valid. At intermediate ranges, the semi-infinite cloud assumption overestimates the dose since it assumes that the concentration (Ci/m^3) everywhere is identical to the ground level concentration, whereas, the concentration

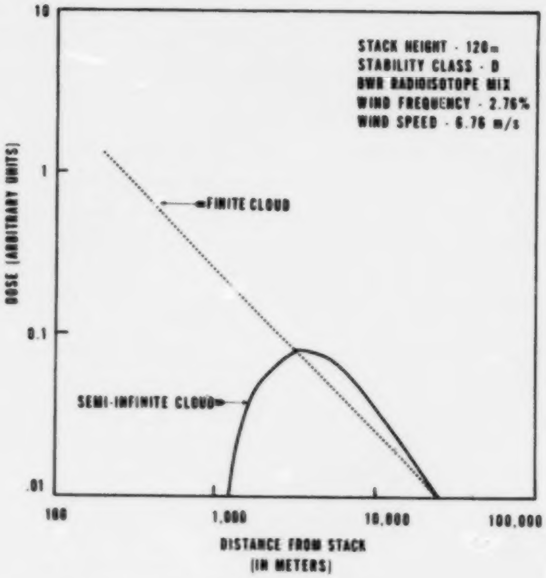

Figure 2. Comparison of external gamma whole-body dose calculated using finite and semi-infinite cloud dose model

actually varies with height. At close distances the semi-infinite cloud assumption results in very low underestimates of doses since the ground level concentration of radionuclides can be orders of magnitude less than the concentration overhead.

Sector-averaged vs. single plume dose calculations

Cloud gamma doses can be calculated using a single plume model, but this approach is not appropriate for long-term average calculations (*10*). AIREM is based on sector-averaged diffusion to be compatible with wind rose data. Figure 3 presents an example of differences in the results obtained using the two diffusion models.

At large ranges, the sector-averaged diffusion equation (assuming a 22.5° sector) leads to calculated doses that are lower than for the single plume. In the sector-averaged model, the activity is uniformly distributed across the sector at all heights, whereas, the single plume model restricts the crosswind horizontal spread of the plume. Thus, the single plume model results in higher centerline doses at large distances from the release point.

At close ranges, AIREM assumes that equal clouds exist in adjacent sectors (figure 4). This results in a higher calculated dose than the single plume model.

Data

Plume rise

Table 1 presents stack data and results of plume rise calculations. Up to 100 meters of plume rise was added to the stack heights of the various BWR's to obtain the effective stack heights (H_{eff}). Dose integral tables were prepared for release heights of 75, 100, 120, 150,

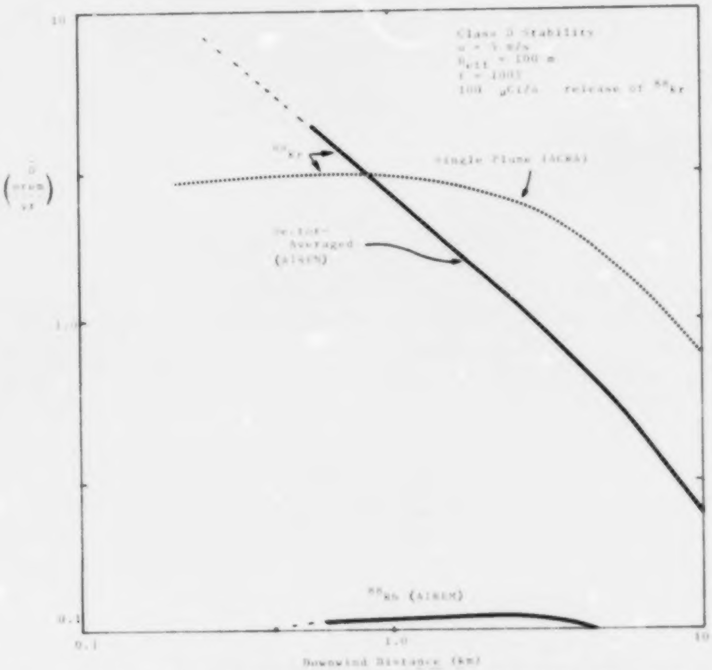

Figure 3. Comparison of cloud gamma dose rate calculated using single plume (ACRA) and sector-averaged (AIREM) diffusion models

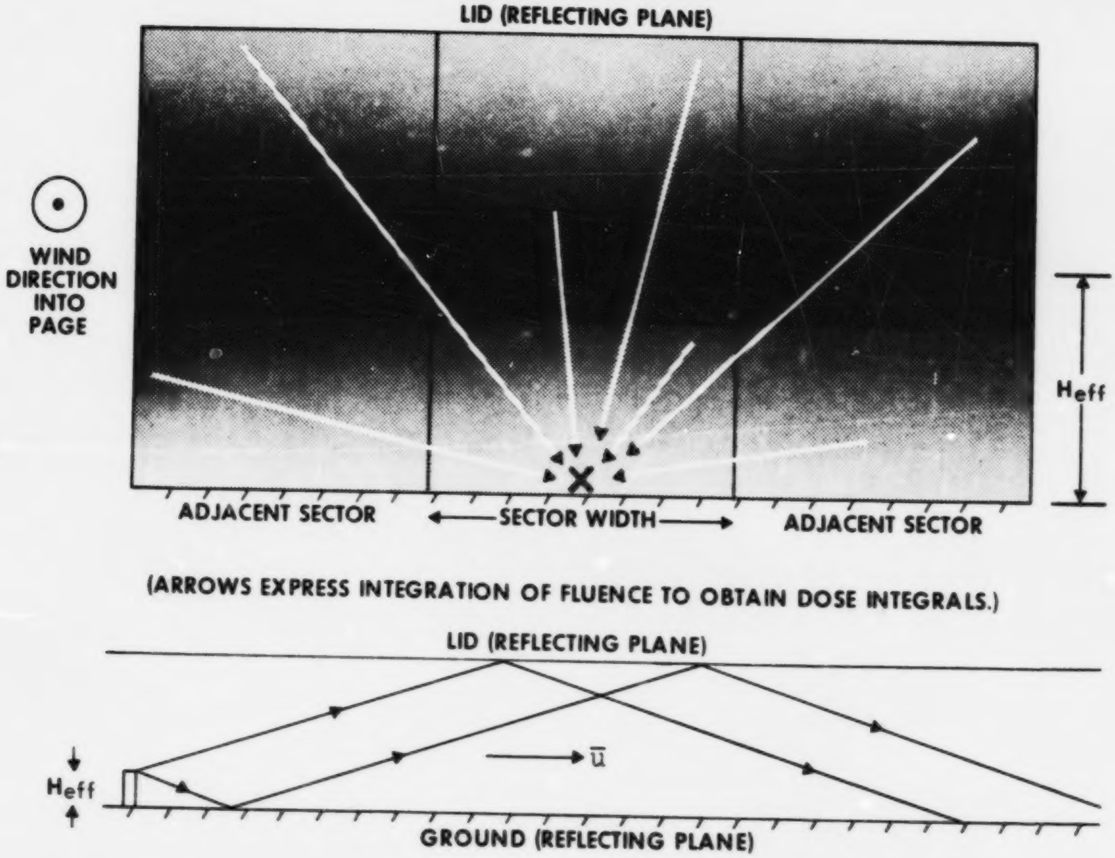
LID (REFLECTING PLANE)
WIND DIRECTION INTO PAGE
H_{eff}
ADJACENT SECTOR
SECTOR WIDTH
ADJACENT SECTOR
(ARROWS EXPRESS INTEGRATION OF FLUENCE TO OBTAIN DOSE INTEGRALS.)
LID (REFLECTING PLANE)
$\bar{u}$
H_{eff}
GROUND (REFLECTING PLANE)

Figure 4. Geometry of AIREM

and 200 meters. AIREM calculations were restricted to the use of one of these values for H_{eff}. The effective stack heights used in the calculations are listed in table 1.

Source terms

Table 2 lists the source terms by radionuclide used in the analyses. These data are a summary of data presented in reference *8*. Although certain anomalies may be observed in this data compilation, no attempt was made to verify these source terms. Also, the reported emissions were presumed to be emitted from the stacks of the BWR's, rather than lower level vents.

Cloud gamma doses

Tables 3 and 4 present the highlights of the results of the cloud gamma dose calculations. Table 3 lists the source terms and maximum doses at the site boundaries; table 4 presents the cloud gamma population doses. All doses are for the first centimeter depth of muscle. Figures 5 and 6 illustrate the growth in population and population dose, respectively, with distance for several facilities. Table 5 illustrates the radionuclide contributions to the population dose in a few selected cases.

15H

Table 1. Calculated plume rise for operating BWR's

Facility	Stack height	I.D.[a] (m)	W_O[b] (m/s)	Q_H[c] (10^3 cal/s)	H_{eff}[d] (m)	H_{eff} used for AIREM calculations (m)
Big Rock Point	75	1.14	12	3.2	108	100
Dresden 1	92	1.22	18	3.5	134	120
Dresden 2, 3	94	3.3	4	25	201	200
Genoa	107	1.37	21	2.1	149	150
Humboldt Bay	75	.45	16	.1	75	75
Millstone-1	115	2.14	24	5.0	168	150
Monticello	100	.36	19	.1	100	100
Nine Mile Point	107	2.6	19	13.2	162	150
Oyster Creek	110	2.5	16	7.4	166	150
Pilgrim	100	.73	19	.3	126	120
Vermont Yankee	94	2.1	18	14	174	150

[a] I.D. Exit diameter of stack.
[b] W_O—Gas exit velocity.
[c] Q_H—Thermal power of stack gases.
[d] Class D stability; 5 m/s winds; Briggs equations.

Table 2. Noble gas radionuclide emissions reported for 1971

Radionuclide	Emissions (kCi)									
	Big Rock Point	Dresden-1	Dresden-2	Dresden-3	Genoa (LaCrosse)	Humboldt Bay	Millstone-1	Monticello	Nine Mile Point	Oyster Creek
Krypton-83m	—	—	—	—	—	15.5	—	—	—	—
Krypton-85m	0.22	33.2	48.4	1.8	0.11	23.7	16.1	5.9	20.3	41.3
Krypton-85	13.9	—	—	—	—	.001	—	—	—	—
Krypton-87	28.5	90.2	84.5	2.0	.01	66.4	17.8	8.9	35.8	72.1
Krypton-88	40.9	82.9	108.3	2.3	.005	75.4	35.5	10.5	33.5	67
Krypton-89	—	—	—	—	—	.033	—	—	—	—
Xenon-133m	—	—	—	—	—	1.35	—	—	—	—
Xenon-133	33.8	54.9	115.1	5.9	.008	49.6	102.6	13.7	42.7	119
Xenon-135m	11.5	147.7	20.2	—	—	45.4	—	—	—	25.8
Xenon-135	77.1	109.3	176.4	2.9	.074	125.6	77.8	15.8	75.4	165
Xenon-137	—	—	—	—	—	.27	—	—	—	—
Xenon-138	67.1	235.6	20.5	.4	.065	108.6	2.45	2.4	22.4	25.8
Total	273	754	573	15.3	[a] 0.56	512	252	[b] 57	230	516

[a] Includes 226 Ci nitrogen-13 and 52 Ci oxygen-15.
[b] Includes 0.132 kCi argon-41.
—, not reported.

Table 3. 1971 summary, BWR emissions and calculated cloud gamma dose

Facility	Energy generated [GW(e)-yr] [a]	Total emissions (kCi)	Maximum dose at site boundary [b-c]		
			Dose (mrem)	Distance (m)	Sector
Big Rock Point	0.041	273	5	668	WSW
Dresden 1	.082	754	12	1 219	SSE
Dresden 2	.30	573	2.6	1 767	S
Dresden 3	.11	15	.06	1 767	S
Genoa	.025	.56	.02	805	S
Humboldt Bay	.039	502	56	254	SE
Millstone-1	.39	252	[d] 3	492	NE
Monticello	.15	57	2.0	704	SSE
Nine Mile Point	.31	230	4.6	335	S
Oyster Creek	.40	516	13	400	NE

[a] Assumes 0.3 electrical to thermal efficiency. 1 GW(e)-yr = 10^9 watt years electric.
[b] No credit given for occupancy factor or building shielding.
[c] Dose scales approximately linearly with distance. Doses to actual individuals were factors of 2 to 3 lower.
[d] Doses at onsite Navy Lab and Desalination Plant are higher by a factor of 1.3.

Inhalation, ingestion, and direct doses from particulates and halogens

There are no direct correlations between locations of maxima for cloud gamma, inhalation, ingestion (e.g., of milk) and direct (from deposited material) doses. Indeed, doses due to these various dose modes usually peak at different locations (ranges and azimuths) about a given site. Some general results may be briefly summarized, however.

Whole body doses due to gamma rays emanating from rubidium-88 and cesium-138 deposited on the ground were calculated and were found to be less than 1 percent of the cloud gamma doses at all distances.

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Table 4. 1971 populations and calculated cloud gamma population doses

Facility	Population within 80 km (millions)	Population dose within 80 km (person-rem)	Average dose per person within 80 km (mrem)
Big Rock Point	0.15	9	0.06
Dresden 1	6.1	330	.05
Dresden 2	6.1	270	.05
Dresden 3	6.1	6	.001
Genoa	[a] .122	[a] .02	<.001
Humboldt Bay	.1	61	.6
Millstone-1	2.5	75	.03
Monticello	2.6	26	.01
Nine Mile Point	1.0	13	.01
Oyster Creek	3.6	115	.03

[a] Forty km radius, population and population dose.

Table 5. Radionuclide contributions to cloud gamma population doses (person-rem) for three population distributions (1971 emissions)

Nuclide	Half life	Humboldt Bay[a]	Monticello[b]	Oyster Creek[c]
Krypton-85m	4.4 h	0.9	0.9	3.5
Krypton-87	76 min	6.3	1.9	9.8
Krypton-88	2.8 h	23.7	12.3	48.7
Rubidium-88	17.8 min	5.0	4.5	17.4
Xenon-133m	2.3 day	0	--------	--------
Xenon-133	5.3 day	.9	1.3	6.6
Xenon-135m	.26 h	1.4	--------	.2
Xenon-135	9.2 h	6.1	4.2	25.8
Xenon-138	14 min	8.9	.1	.6
Cesium-138	32 min	8.0	.3	2.6
Total		61.2	25.5	115.2

[a] Pacific site-majority of population is within 8 km (5 miles) to N and S.
[b] Inland site-major population center is 50 km (35 miles) to SSE in predominant wind direction.
[c] Atlantic site-large population centers at 80 km (50 miles) to N and W.

At distances within 2 km of a 100 m (or higher) stack, the total whole body dose due to rubidium-88 and cesium-138 is less than 1 percent of the cloud gamma dose due to all noble gases. This total includes the inhalation whole body dose and the external gamma dose due to the radionuclides deposited on the ground. However, because of continued ingrowth, these radionuclides can contribute 15 to 20 percent of the total cloud gamma population dose within 80 km.

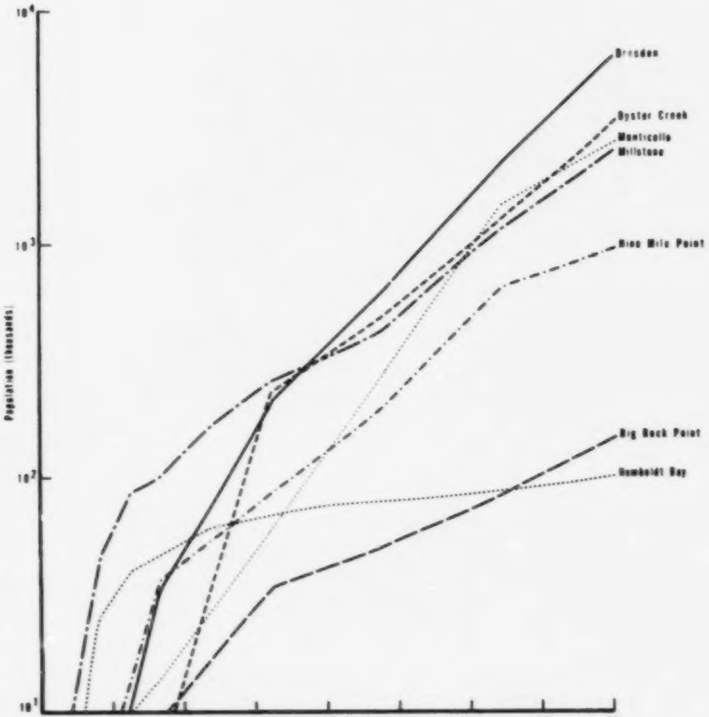

Figure 5. Growth in population with distance

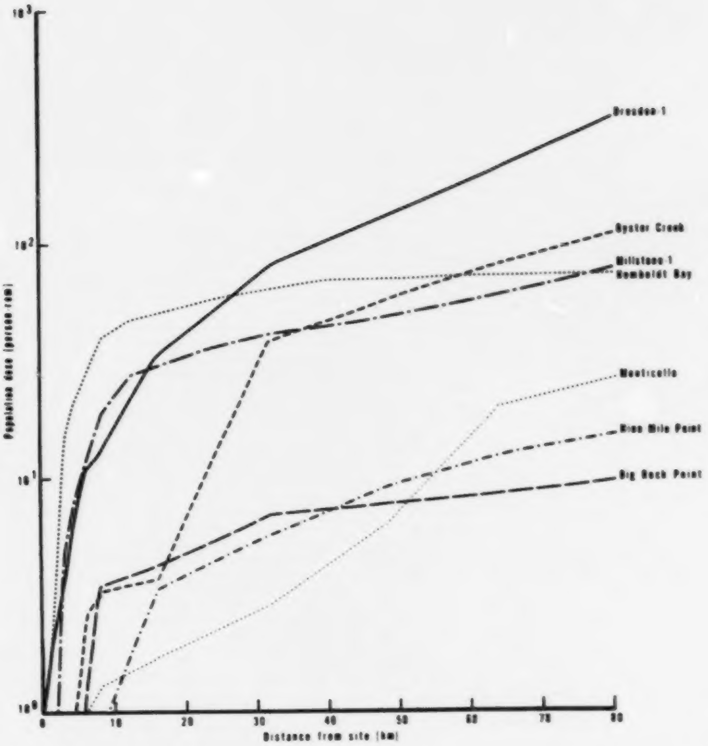

Figure 6. Growth in cloud gamma population dose with distance

Figure 7 illustrates the calculated concentration of iodine-131 in milk for several effective release heights. Listed in the figure are some of the assumptions used in the calculations. The data apply to a typical maximum wind frequency sector; concentrations in other sectors and for other wind doses may be lower by as much as a factor of 10 and higher by a factor of 5. Displayed are average saturated activity levels; levels may be substantially higher and lower over periods of several days depending upon local weather conditions.

As illustrated in figure 8, 50 to 70 percent of the iodine-131 release leaves the 50-mile radius considered in the computer runs. Because of the latter observation, it is clear that on an annual average basis, cloud depletion by ground deposition, although considered in AIREM, is not a very important consideration for deposition velocities near the typically assumed value (*11*) of 1 cm/s. A corollary is that calculated ground deposition and milk concentrations (where there are dairy herds) increase monotonically with the deposition velocity assumed in the calculations.

Table 6 presents iodine-131 ground deposition calculations for BWR's operating in 1971. Because of the uncertainty in the deposition velocity assumed for iodine emissions and the lack of cow density and milk pool data, ingestion doses have not been calculated. (Note: for a 1-year-old child, a daily consumption of 1 liter of milk having an iodine-131 concentration of 1 pCi/liter would result in a thyroid dose rate of 5 mrem/yr (*12, 13*).

Inhalation and skin doses

Doses due to inhalation of iodine-131 (where

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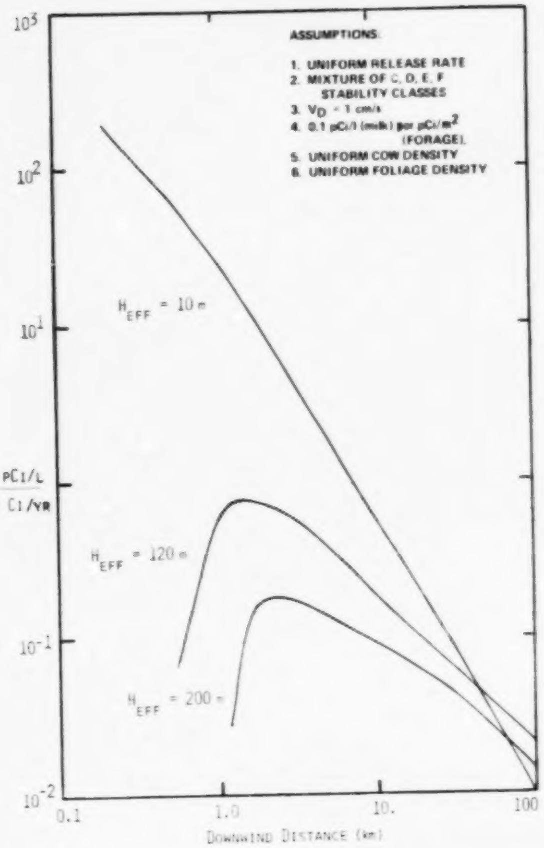

Figure 7. Iodine–131 concentration in milk in a typical high-frequency sector (per curie released)

source terms were provided in reference 5) are also listed in table 6. These were all small fractions of the cloud gamma doses. Lung doses from rubidium-88 and cesium-138 were not calculated due to the lack of an adequate model.

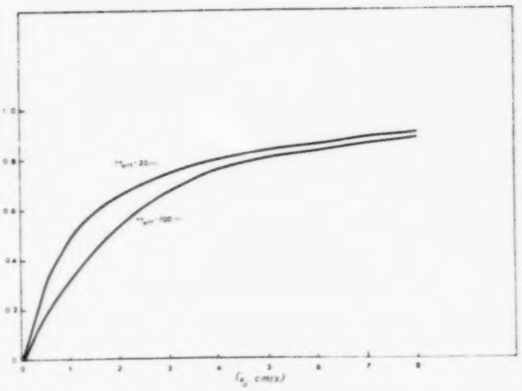

Figure 8. Fraction of release deposited within 50 miles vs. deposition velocity (mixture of stability classes)

Doses to the skin (epidermis) due to external beta particles are not tabulated since these calculations were performed in only a few cases. As a general rule of thumb, for elevated releases the skin population dose was approximately one-half the cloud gamma population dose. However, at the site boundaries, external beta skin doses were all small compared to the cloud gamma doses at the site boundaries. Further, since beta particles are attenuated very strongly in the 'dead' layer of skin (to a depth of 7 mg/cm^2 or so), the external beta dose delivered to living tissue was very small compared to the cloud gamma dose.

Health effects

Recently, the National Academy of Science Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) has summarized

Table 6. Calculated iodine-131 data (1971 releases)

Facility	Heff (m)	Activity release (curies)	Population dose[a] 80 km (person-rem)	Maximum saturated activity[b] (ground)		
				(pCi/m^2)	Distance (km)	Sector
Big Rock Point	100	[c]0.3	0.5	2	3	NNE
Dresden 1	120	.49	1.5	4	2.4	SSE & NW
Dresden 2, 3	200	8.1	10	33	2.4	SSE & NW
Genoa	150	.001		Negligible		
Humboldt Bay	75	.30	.10	11	.6	N
Millstone–1	150	3.94	4.4	20	2.4	ENE
Monticello	100	.04	.05	.9	1.2	SSE
Nine Mile Point	150	.78	.15	7	1.2	N
Oyster Creek	150	1.33	1.5	20	2.4	N

[a] Thyroid dose due to inhalation of iodine-131. An age weighted dose conversion factor of 15.6 mrem/a per pCi/m^3 was used (4).
[b] Assumes 1 cm/s deposition velocity, stack release.
[c] Estimated release.

Table 7. Calculated health effects from natural background and cloud gamma population doses in 1971

Facility	Population (millions)	Energy produced (GW(e)-yr)	Noble gas emissions (kCi)	Health effects	
				Natural background [a]	Cloud gamma
Big Rock Point	0.15	0.041	273	9.	0.006
Dresden 1, 2, and 3	6.1	.492	1342	370.	.42
Humboldt Bay	.1	.039	502	5.	.043
Genoa (La Crosse)	.12	.025	.56	8.	<.001
Millstone-1	2.5	.39	252	160.	.053
Monticello	2.6	.15	57	140.	.018
Nine Mile Point	1.0	.31	230	65.	.009
Oyster Creek	3.6	.40	516	160.	.081

[a] Gamma background including cosmic ray dose was taken from reference *16*.

the present state of knowledge in radiation risk prediction in their report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation" (*14*). Using the health risk estimates for chronic exposures given in the BEIR Report, the expected number of radiation induced health effects can be calculated for various sources of environmental exposure. Such estimates are based on the conservative, but commonly held assumptions, that radiation effects are directly proportional to the dose and that the number of cancers per rem that have been observed at high doses and dose rates is an adequate predictor of effects per rem at the low doses and dose rates encountered from environmental sources.

The risk values given in the BEIR Report were used to estimate the number of potential health effects from external gamma radiation likely to occur in the population residing within 80 km of operating BWR power stations. Two sources of radiation were considered, natural background radiation, and the external gamma radiation from gaseous atmospheric reactor emissions. The calculated health effects, based upon a risk factor of 7×10^{-4} health effects per person-rem (*15*) are presented in table 7. It is apparent that the number of health effects occurring is a strong function of population size and to a lesser extent dependent on the size and emission control characteristics of the individual reactors.

Discussion of calculational uncertainties

In these calculations, all major physical processes have been taken into account with operational state-of-the-art mathematical techniques. The predominant sources of error lie in the basic assumptions of the invariant wind, the gaussian cloud diffusion model and the diffusion constants used in these calculations. After some 50 years of experience, discrepancies of a factor of 2 (either way) between this theory and field experiments are commonly found within a few kilometers of an emission point (*2, 10, 17*). Considering all error sources, actual site boundary doses were probably within a factor of 3 of the calculated doses. Based upon examination of a few selected cases, maximum doses to real individuals would have been less than the site boundary doses by at least a factor of 2, had occupancy factors, building shielding, the decrease in dose with distance, and locations of nearest residents been considered.

Calculated population doses are even more uncertain. Siting practices in the United States are such that most of the population dose is accumulated at ranges of several tens of kilometers, i.e., at the major population centers. At these ranges, discrepancies between the wind invarient gaussian plume dispersion model predictions and experimental measurements are of the order of a factor of 10 either way (*10*). However, it has recently been shown (*18*) that this model can considerably underestimate dilution at distances of 30 to 50 km. Based upon some preliminary calculations, it was estimated in this study that the calculated population doses could have been overestimated by factors of between 2 and 5.

Risk estimates based on the BEIR Report are by no means precise. For example, predictions of the number of fatal cancers per rem vary by a factor of about 4 depending on the model used. The risk factor used herein corresponds to the "most likely value" chosen by the BEIR Committee. A more detailed explanation of EPA's application of BEIR data to risk estimates for nuclear facilities has been published in Environmental Analysis of the Uranium Fuel Cycle, Part III, Nuclear Fuel Reprocessing (EPA-520/9-73-003-D) (*15*). As defined in the document, potential health effects from radiation include fatal cancers, nonfatal cancers, and genetic effects in the approximate ratios of 2:2:3, respectively. Somatic effects are assumed to occur within 30 years or so of exposure; genetic effects extend over several generations.

Another potential source of error is the assumption that all radionuclides were emitted from the stacks of these BWR's. This uncertainty affects the iodine deposition calculations more than the cloud gamma dose calculations. Since the facilities do not report releases by release height (nor by chemical form in the case of the iodines), the iodine ground deposition density data in table 6 are uncertain.

Discussion

In 1971, 10 boiling water nuclear power reactors in the United States produced about 1.5 gigawatts-years of electrical energy. These facilities released a total of 3.2 million curies of activity to the air, which resulted in a calculated cloud gamma population dose of 900 person-rem to the residents within 80 km of these facilities. Other pathways were not considered in these calculations. The average whole body dose to individuals within 80 km of all BWR's operating in 1971 was about 0.06 mrem. In all cases considered, calculated health effects due to cloud gamma exposures were small compared to those from natural background.

As illustrated by the data in table 5, krypton-87, krypton-88, its daughter rubidium-88, xenon-135 and xenon-133 were the major contributors to cloud gamma population doses. These isotopes have half-lives of 76 min, 2.8 h, 18 min, 9.2 h, and 5.3 days, respectively. Other contributors have shorter half-lives. The BWR's considered in this report typically employ holdup times on the order of 0.5 hour for those gases released from the air ejector. Figure 9 illustrates the decrease in cloud gamma dose as a function of additional in-plant holdup time, calculated for a particular case. It is apparent that an additional in-plant holdup of even a few hours would significantly reduce radiation exposures to the general population. A holdup of 10 hours could reduce exposures by as much as 90 percent. Upon application of the numerical guidelines proposed by the AEC (*19*), substantial reductions in the population dose per GW(e)-yr should be expected in the future.

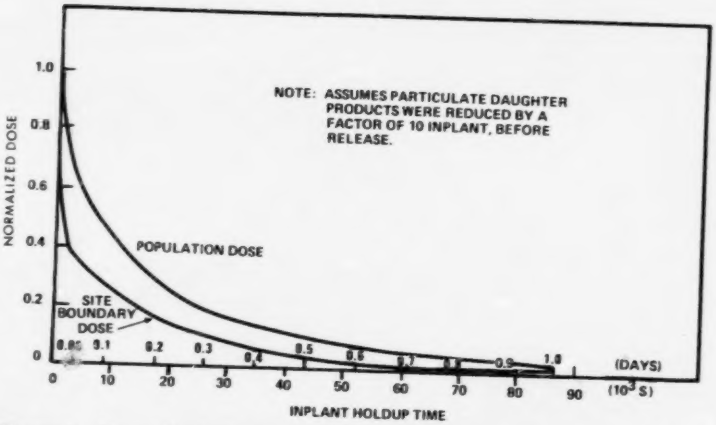

Figure 9. Normalized site boundary and population cloud gamma doses as a function of additional holdup time (1971 Dresden-1 case)

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, January 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

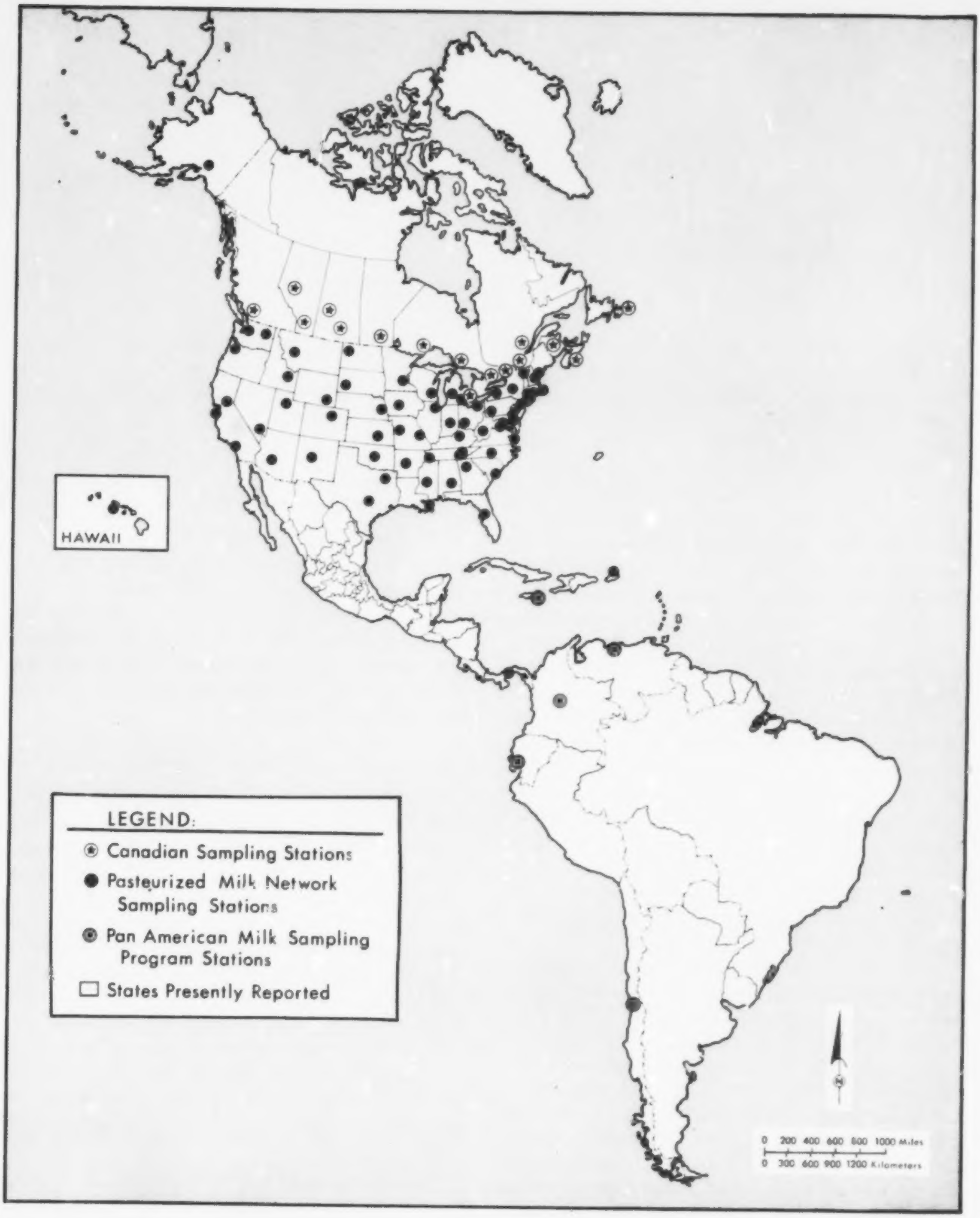
HAWAII
LEGEND:
Canadian Sampling Stations
Pasteurized Milk Network Sampling Stations
Pan American Milk Sampling Program Stations
States Presently Reported
0 200 400 600 800 1000 Miles
0 300 600 900 1200 Kilometers
N

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Program conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable[a]	Warning level[b]	Unacceptable[c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels < 50 pCi/liter; 5–10% for levels ≧ 50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels < 20 pCi/liter; 4–10% for levels ≧ 20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels < 100 pCi/liter; 4–10% for levels ≧ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels < 100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks dis-

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Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]
UNITED STATES:						
Ala:	Montgomery[e]	P	NA	4	0	3
Alaska:	Palmer[e]	P	NA	4	0	1
Ariz:	Phoenix[e]	P	NA	0	0	0
Ark:	Little Rock[e]	P	NA	10	0	1
Calif:	Los Angeles[e]	P	NA	0	0	0
	Sacramento[e]	P	NA	1	0	0
	San Francisco[e]	P	NA	0	0	0
	Del Norte	P	13	11	0	5
	Fresno	P	2	1	0	1
	Humboldt	P	3	3	0	1
	Los Angeles	P	2	1	0	2
	Mendocino	P	3	2	0	1
	Sacramento	P	1	2	0	3
	San Diego	P	2	1	0	1
	Santa Clara	P	2	2	0	2
	Shasta	P	2	2	0	2
	Sonoma	P	1	2	0	3
Colo:	Denver[e]	P	NA	3	0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	2
	South Central	R	NS	NA	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NS	NA	NS	0
	West	R	NS	NA	NS	0
Conn:	Hartford[e]	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington[e]	P	NA	6	0	2
D.C:	Washington[e]	P	NA	3	0	1
Fla:	Tampa[e]	P	NA	4	14	25
	Central	R	4	5	14	26
	North	R	5	6	25	15
	Northeast	R	6	6	18	29
	Southeast	R	5	5	36	46
	Tampa Bay area	P	5	5	17	28
	West	R	8	8	0	9
Ga:	Atlanta[e]	P	NA	4	0	5
Hawaii:	Honolulu[e]	P	NA	0	0	0
Idaho:	Idaho Falls[e]	P	NA	4	0	0
Ill:	Chicago[e]	P	NA	5	0	1
Ind:	Indianapolis[e]	P	NA	5	0	2
	Central	P	4	5	0	6
	Northeast	P	5	5	15	10
	Northwest	P	7	7	15	9
	Southeast	P	5	6	10	8
	Southwest	P	4	7	0	7
Iowa:	Des Moines[e]	P	NA	4	0	0
	Des Moines	P	4 (3)	5	0 (3)	0
	Iowa City	P	5	5	0	0
	LeMars	P	6	6	0	0
	Little Cedar	P	6	6	0	0
Kans:	Wichita[e]	P	NA	5	0	1
	Coffeyville	P	3	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	P	5	6	13	7
	Hays	P	3	6	0	5
	Kansas City	P	5	5	0	6
	Topeka	P	3	6	10	5
	Wichita	P	6	6	12	7
Ky:	Louisville[e]	P	NA	5	0	2
La:	New Orleans[e]	P	NS	7	NS	1
Maine:	Portland[e]	P	NA	4	0	14
Md:	Baltimore[e]	P	NA	6	0	3
Mass:	Boston[e]	P	NA	7	0	9
Mich:	Detroit[e]	P	NA	6	0	3
	Grand Rapids[e]	P	NA	7	0	1
	Bay City	P	14	10	0	1
	Charlevoix	P	7	9	0	1
	Detroit	P	21	8	0	0
	Grand Rapids	P	23	11	14	3
	Lansing	P	17	11	6	3
	Marquette	P	14	10	0	7
	Monroe	P	6	13	0	1
	South Haven	P	27	13	0	3
Minn:	Minneapolis[e]	P	NA	7	0	1
	Bemidji	P	7	7	0	11
	Duluth	P	15	16	16	17
	Fergus Falls	P	8	6	0	0
	Little Falls	P	NS	17	NS	27
	Mankato	P	5	5	0	0
	Marshall	P	3	3	0	0

See footnotes at end of table.

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Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]
Minn:	Minneapolis	P	9	9	0	0
	Rochester	P	6	6	0	0
Miss:	Jackson[c]	P	NA	8	0	6
Mo:	Kansas City[c]	P	NA	4	0	0
	St. Louis[c]	P	NA	8	0	1
Mont:	Helena[c]	P	NA	2	0	0
Nebr:	Omaha[c]	P	NA	2	0	0
Nev:	Las Vegas[c]	P	NA	5	0	0
N.H:	Manchester[c]	P	NA	6	0	8
N.J:	Trenton[c]	P	NA	5	0	2
N. Mex:	Albuquerque[c]	P	NA	0	0	0
N.Y:	Buffalo[c]	P	NA	5	0	3
	New York City[c]	P	NA	4	0	3
	Syracuse[c]	P	NA	6	0	1
	Albany	P	5	4	0	0
	Buffalo	P	3	5	0	0
	Massena	P	7	7	0	10
	New York City	P	NA	7	14	0
	Syracuse	P	NS	6	NS	0
N.C:	Charlotte[c]	P	NA	7	0	5
N. Dak:	Minot[c]	P	NA	6	0	0
Ohio:	Cincinnati[c]	P	NA	5	0	3
	Cleveland[c]	P	NA	6	0	2
Okla:	Oklahoma City[c]	P	NA	3	0	0
Oreg:	Portland[c]	P	NA	4	0	1
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	P	NA		NA	
Pa:	Philadelphia[c]	P	NA	5	0	2
	Pittsburgh[c]	P	NA	9	0	3
	Dauphin	P	5	4	0	0
	Erie	P	6	6	0	0
	Philadelphia	P	4	4	0	0
	Pittsburgh	P	4	5	0	0
R.I:	Providence	P	NS	4	NS	5
S.C:	Charleston[c]	P	NA	5	0	5
	Chapin	R	NS	8	NS	15
	Clemson	R	NS	8	NS	10
	Columbia	R	7	8	10	11
	Fairfield	R	6	7	10	12
	Hartsville-02	R	NS	7	NS	11
	Hartsville-03	R	NS	16	NS	14
	Lee County	R	NS	8	NS	15
	Oconee County	R	NS	8	NS	9
	Pickens	R	NS	7	NS	8
	Williston	R	NS	7	NS	17
	Winnsboro	R	7	7	11	15
S. Dak:	Rapid City[c]	P	NA	6	0	1
Tenn:	Chattanooga[c]	P	NA	6	0	1
	Knoxville[c]	P	NA	0	0	0
	Memphis[c]	P	NA	6	0	2
	Chattanooga	P	NA	7	0	3
	Clinton	R	NA	6	14	4
	Fayetteville	R	NA	6	6 (2)	3
	Kingston	R	NA	7	5	0
	Knoxville	P	NA	5	19	3
	Lawrenceburg	R	NA	3	0	6
	Nashville	P	NA	4	10	3
	Pulaski	R	NA	6	5	0
	Sequoyah	R	NS	9	NS	6
Tex:	Austin[c]	P	NA	0	0	0
	Dallas[c]	P	NA	4	0	0
Utah:	Salt Lake City[c]	P	NA	2	0	0
Vt:	Burlington[c]	P	NA	4	0	5
Va:	Norfolk[c]	P	NA	6	0	1
Wash:	Seattle[c]	P	NA	1	0	0
	Spokane[c]	P	NA	5	0	0
	Benton County	R	0	0	0	0
	Franklin County	R	NS	1	NS	0
	Longview	R	5	4	17	5
	Sandpoint, Idaho	R	5	5	0	1
	Skagit County	R	4	4	0	0
W. Va:	Charleston[c]	P	NA	7	0	2
Wisc:	Milwaukee[c]	P	NA	[illegible]	0	1
Wyo:	Laramie[c]	P	NA	1	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for January 1974 and 12-month period, February 1973 through January 1974—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:						
Alberta:	Calgary	P	NA		4	7
	Edmonton	P	NA		6	12
British Columbia:	Vancouver	P	NA		11	13
Manitoba:	Winnipeg	P	NA		6	10
New Brunswick:	Moncton	P	NA		10	9
Newfoundland:	St. John's	P	NA		6	15
Nova Scotia:	Halifax	P	NA		4	10
Ontario:	Ottawa	P	NA		5	6
	Sault Ste. Marie	P	NA		11	16
	Thunder Bay	P	NA		8	11
	Toronto	P	NA		4	6
	Windsor	P	NA		3	6
Quebec:	Montreal	P	NA		NS	
	Quebec	P	NA		15	12
Saskatchewan:	Regina	P	NA		3	7
	Saskatoon	P	NA		6	7
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	10	NS	13
Chile:	Santiago	P	0	0	0	0
Colombia:	Bogota	P	NS	1	NS	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Kingston	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	1	0	2
PMN network average[d]			NA	4	0	2

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

cussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports*. The relationship between the PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for January 1974 and the 12-month period, February 1973 to January 1974. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for January

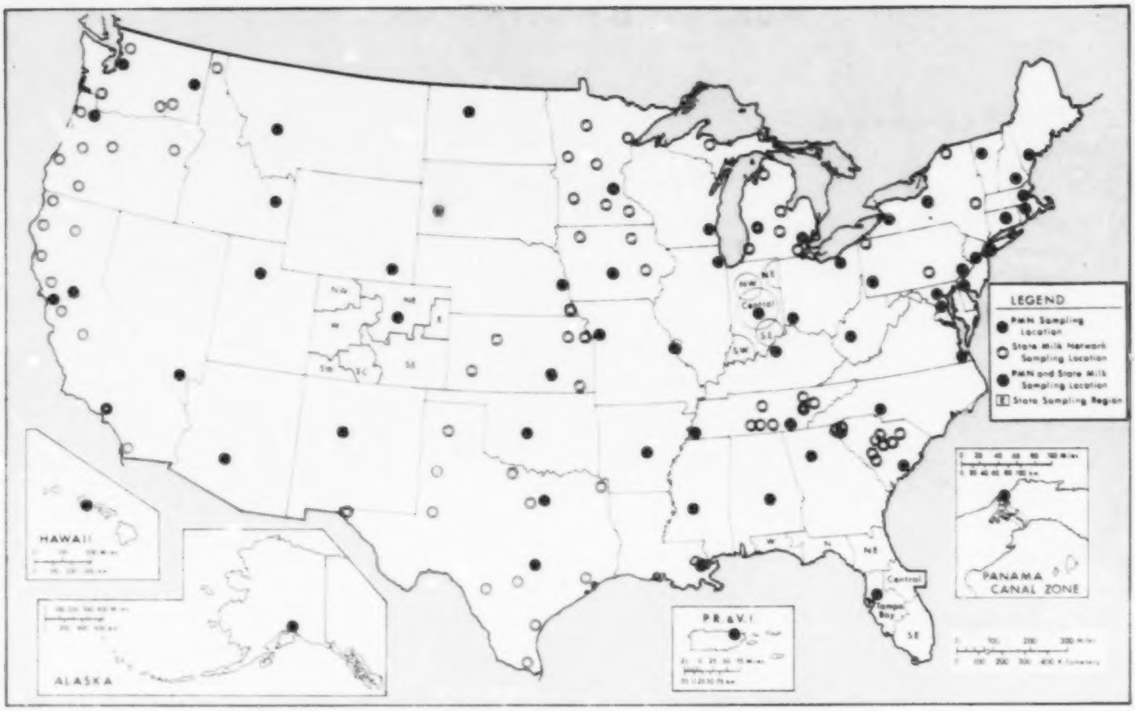

Figure 2. State and PMN sampling stations in the United States

1974 were below the respective practical reporting levels with one exception. The following station average reflects a sample in which strontium-89 was detected: Calif: Del Norte (State), 10 pCi/liter.

Strontium-90 monthly averages ranged from 0 to 27 pCi/liter in the United States for January 1974 and the highest 12-month average was 17 pCi/liter (Little Falls, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 36 pCi/liter in the United States for January 1974, and the highest 12-month average was 46 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report. Table 3 gives the strontium-89 and strontium-90 results of PMN milk samples composited by region.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Table 3. Strontium-90[a] results of PMN milk samples composited by region

EPA region	States located in region	Strontium-90 concentration (pCi/liter)
I	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	4
II	New Jersey, New York, Puerto Rico	3
III	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia	6
IV	Alabama, Canal Zone, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	5
V	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	5
VI	Arkansas, Louisiana, New Mexico, Oklahoma, Texas	5
VII	Iowa, Kansas, Missouri, Nebraska	4
VIII	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	3
IX	Arizona, California, Hawaii, Nevada	0
X	Alaska, Idaho, Oregon, Washington	3

[a] All strontium-89 results were less than the practical reporting level (5 pCi/liter).

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Milk Surveillance Network, First Quarter 1974

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Milk Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV) consists of 24 routine and 1 alternate sampling locations (figure 1) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS).

In the event of a release of radioactivity from the NTS, special sampling within the affected

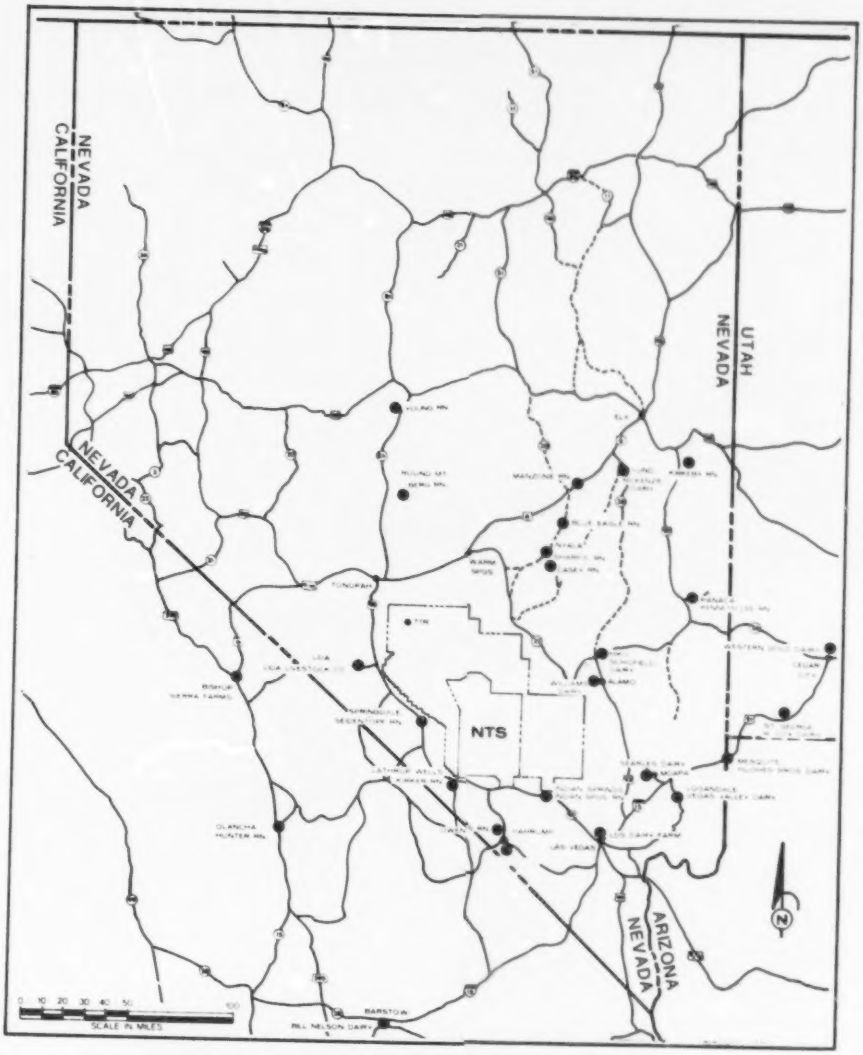
NEVADA
CALIFORNIA
UTAH
NEVADA
ARIZONA
NEVADA
NTS
TONOPAH
ELY
ROUND MT
BLUE EAGLE RN
NYALA
CASEY RN
WARM SPGS
PANACA
HIKO
ALAMO
WILLIAMS DAIRY
WESTERN
CEDAR CITY
ST GEORGE
MESQUITE
HUGHES BROS DAIRY
SEARLES DAIRY
MOAPA
LOGANDALE
VEGAS VALLEY DAIRY
INDIAN SPRINGS
LATHROP WELLS
PAHRUMP
LAS VEGAS
LIDA
SPRINGDALE
BISHOP
OLANCHA
BARSTOW
BILL NELSON DAIRY
0 10 20 30 40 50 100
SCALE IN MILES
N

Figure 1. NERC-LV Milk Surveillance Network

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[1] This network is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

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Table 1. Milk surveillance results, First Quarter 1974

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)			
			Cesium-137	Strontium-89	Strontium-90	Tritium
California:						
Bishop:						
Sierra Creamery	1/17	11	<10	<2.7	1.4±1.1	NA
Hinkley:						
Bill Nelson Dairy	1/15	12	<10	<2.6	1.5±1.0	NA
Olancha:						
Hunter Ranch	NS					
Nevada:						
Alamo:						
Williams Dairy	NS					
Austin:						
Young's Ranch	1/8	13	<10	<3.4	1.6±1.3	830±250
Currant:						
Blue Eagle Ranch	1/17	13	<10	<2.4	<2.0	NA
Manzonie Ranch	1/16	13	<10	<2.7	2.0±1.1	NA
Hiko:						
Schofield Dairy	1/7	12	<10	<4.2	3.8±1.6	<240
Indian Springs:						
Indian Springs Ranch	1/11	13	<10	<2.9	<1.1	NA
Las Vegas:						
LDS Dairy Farms	1/14	12	<10	<2.9	<1.2	290±240
Lathrop Wells:						
Kirker Ranch	1/11	13	<10	<3.3	<1.3	NA
Lida:						
Lida Livestock Company	1/6	13	<10	<3.7	2.6±1.4	NA
Logandale:						
Vegas Valley Dairy	1/15	12	<10	<5.5	3.0±2.2	NA
Lund:						
McKenzie Dairy	1/16	12	<10	<2.4	2.0±1.0	<230
Mesquite:						
Hughes Bros. Dairy	1/15	12	<10	<3.2	<1.2	<230
Moapa:						
Searles Dairy	1/15	12	<10	<3.6	1.9±1.4	NA
Nyala:						
Sharp's Ranch	1/8	13	<10	<3.6	2.5±1.3	250±240
Pahrump:						
Burson Ranch	1/11	13	<10	<3.2	<1.2	NA
Panaca:						
Kenneth Lee Ranch	1/11	13	<100	<3.3	1.8±1.3	NA
Round Mountain:						
Berg Ranch	1/8	13	<10	<3.5	<1.3	NA
Shoshone:						
Kirkeby Ranch	1/15	13	<10	<2.8	2.5±1.2	NA
Springdale:						
Seidentopf Ranch	1/10	13	<10	<3.3	<1.3	NA
Utah:						
Cedar City:						
Western Gold Dairy	1/16	12	<10	<3.2	3.3±1.3	NA
St. George:						
R. Cox Dairy	1/17	12	<10	<3.1	<1.3	NA

[a] 11–Pasteurized milk.
12–Raw milk from Grade A producer(s).
13–Raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased minimum detectable activity.
NA, no analysis.
NS, no sample.

area is conducted to determine radionuclide concentrations. Additional milk sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the milk results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The analytical results of all milk samples collected in the first quarter of 1974 by NERC–LV are listed in table 1. With the exception of cesium-137 at levels near the minimum detectable concentration (MDC) of 10 pCi/liter, no gamma-emitting fission products were identified by gamma spectrometry in any of the samples collected in the first quarter. Levels of tritium near the MDC for this radionuclide (~ 200 pCi/liter) were also measured by liquid scintillation counting techniques. The highest concentration of tritium during the first quarter was 830 ± 250 pCi/liter.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Institutional Diet	April–June 1973	March 1974
Strontium-90 in Tri-City Diets	1972	December 1973

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SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommndations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium-90 and alpha-particle emitters, the limit is 1 000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
ERAMS Surface Water and Drinking Water Components	July–September 1973	May 1974
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1970–June 1971	November 1972
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

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(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

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(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Water Surveillance Network, First Quarter 1974

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Water Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 59 sampling locations (figures 1 and 2) in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing conducted by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site.

In the event of a release of radioactivity from the NTS, special sampling within the affected area is conducted to determine radionuclide con-

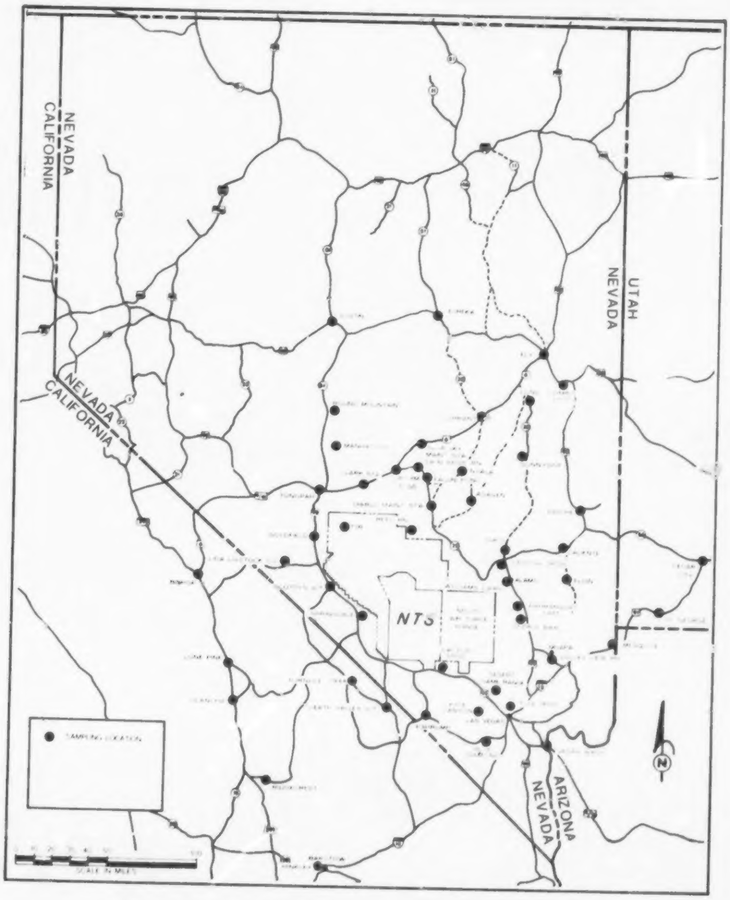
NEVADA
CALIFORNIA
NEVADA
CALIFORNIA
UTAH
NEVADA
ARIZONA
NEVADA
NTS
EUREKA
ELY
TONOPAH
ALAMO
LAS VEGAS
SAMPLING LOCATION
SCALE IN MILES
N

Figure 1. NERC–LV Water Surveillance Network

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[1] This network is operated under a Memorandum of Understanding (No. AT(26–1)–539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

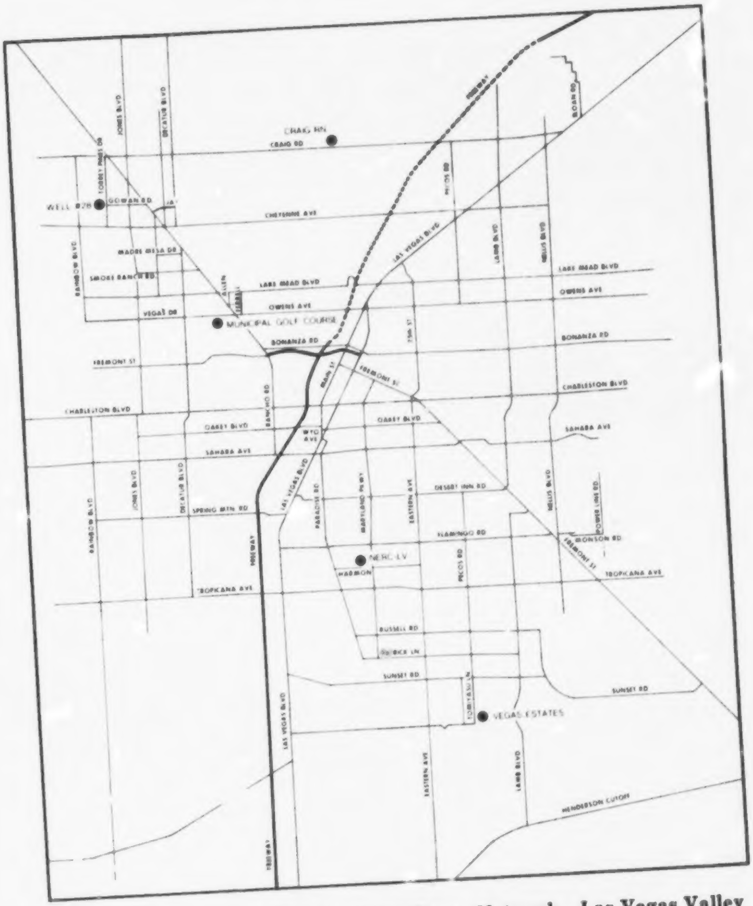
CRAIG RN
CRAIG RD
WELL #28
GOWAN RD
TORREY PINES DR
JONES BLVD
DECATUR BLVD
CHEYENNE AVE
FREEWAY
PECOS RD
SLOAN RD
LAS VEGAS BLVD
LAMB BLVD
NELLIS BLVD
MADRE MESA DR
SMOKE RANCH RD
RAINBOW BLVD
LAKE MEAD BLVD
OWENS AVE
VEGAS DR
MUNICIPAL GOLF COURSE
BONANZA RD
FREMONT ST
25th ST
MAIN ST
CHARLESTON BLVD
RANCHO RD
OAKEY BLVD
WYO AVE
SAHARA AVE
DESERT INN RD
SPRING MTN RD
PARADISE RD
MARYLAND PKWY
EASTERN AVE
FLAMINGO RD
MONSON RD
POWER LINE RD
NERC-LV
HARMON
TROPICANA AVE
RUSSELL RD
SUNSET RD
TOMIYASU LN
VEGAS ESTATES
HENDERSON CUTOFF

Figure 2. NERC–LV Water Surveillance Network—Las Vegas Valley

centrations. Additional water sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the water results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The routine analytical results of all water samples collected in the first quarter of 1974 by the NERC–LV are listed in table 1. No gamma-emitting fission products were identified by gamma spectrometry in any of the first quarter samples.

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Table 1. Water surveillance results, First Quarter 1974

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
California:					
Bishop:					
Fish and Game Office	1/17	23	<1.6	<3.2	NA
Death Valley Junction:					
Lila's Cafe	1/8	23	<2.4	7.5 ±3.7	<240
Furnance Creek:					
Pond	1/8	21	<4.5	8.4 ±3.6	NA
Visitor's Center	1/8	27	6.2 ±4.6	11 ±3.8	NA
Hinkley:					
Bill Nelson Dairy	1/15	23	7.1 ±5.0	9.6 ±3.7	NA
Lone Pine:					
Forest Service Ranger Station	1/16	24	<1.7	<3.2	NA
Olancha:					
Haiwee Reservoir	1/15	21	6.6 ±4.0	7.9 ±3.5	NA
Ridgecrest:					
City Hall	1/15	23	<3.6	4.5 ±3.3	NA
Nevada:					
Adaven:					
Canfield Ranch	1/16	22	4.5 ±3.0	4.0 ±3.0	NA
Alamo:					
Pahranagat Lake	1/7	21	<3.6	15 ±4.0	NA
Sheri's Bar	1/7	23	<2.6	6.8 ±3.5	NA
Williams Dairy	1/7	23	<2.8	16 ±4.0	NA
Austin:					
Nevada National Bank	1/9	27	26 ±6.5	25 ±4.4	NA
Blue Diamond:					
Post Office	1/11	23	<2.5	<3.2	<240
Blue Jay Highway Maintenance Station	1/17	23	3.3 ±2.9	7.6 ±3.3	NA
Cactus Springs:					
Mobil Service Station	1/9	27	2.8 ±2.2	<3.2	<240
Caliente:					
Agricultural Extension Station	1/10	23	11 ±4.9	12 ±3.7	NA
Clark Station:					
Five Mile Ranch	1/17	27	<2.1	6.9 ±3.2	NA
Currant:					
Currant Ranch Cafe Diablo	1/16	27	7.8 ±5.1	5.8 ±3.2	NA
Highway Maintenance Station	1/9	23	<2.4	11 ±3.7	NA
Reed Ranch	1/7	21	18 ±6.5	9.3 ±3.6	NA
Elgin:					
Water tower	1/11	23	6.3 ±4.7	12 ±3.8	NA
Ely:					
Chevron Service Station	1/15	24	2.8 ±2.2	<2.9	NA
Comins Lake	NS				
Eureka:					
Highway Maintenance Station	1/15	24	<2.3	<3.0	NA
Goldfield:					
Chevron Service Station	1/8	23	<2.7	4.0 ±3.2	NA
Hiko:					
Crystal Springs	1/10	27	9.3 ±4.6	9.2 ±3.6	NA
Schofield Dairy	1/7	23	32 ±9.3	39 ±5.1	NA
Las Vegas:					
Craig Ranch Golf Course	1/14	23	2.7 ±2.3	<3.2	<240
Desert Game Range	1/9	23	7.7 ±3.6	<3.2	<240
Lab I, NERC	1/14	24	<3.0	<3.1	550 ±240
Lake Mead Vegas Wash	1/14	21	5.7 ±4.5	6.2 ±3.5	680 ±250
Las Vegas Water District Well 28	1/14	23	2.4 ±2.2	<3.2	<240
Municipal Golf Course	1/14	23	2.7 ±2.6	4.9 ±3.3	<240
Tule Springs	1/7	23	4.1 ±2.7	<3.2	<240
Tule Springs Pond	1/17	21	9.2 ±4.0	7.1 ±3.4	NA
Vegas Estates	1/14	23	4.7 ±4.4	10 ±3.8	<240
Lida:					
Lida Livestock Company	1/7	27	<2.8	<3.0	NA
Pond at storage tank	1/7	21	<2.3	3.1 ±3.0	NA
Lund:					
Gardner Grocery	1/16	23	6.3 ±3.7	<3.0	NA
Manhattan:					
Country store	1/10	23	27 ±8.3	7.1 ±3.4	NA
Mesquite:					
Hughes Bros. Dairy	1/15	23	<3.1	8.5 ±3.4	NA
Moapa:					
Pedersen Valley View Ranch	1/15	27	9.3 ±5.6	14 ±4.0	NA
Mt. Charleston:					
Kyle Canyon Fire Station	1/7	27	<1.9	<3.2	<240
Nyala:					
Sharp's Ranch	1/8	23	3.6 ±2.9	<3.2	NA
Pahrump:					
Texaco Service Station	1/11	23	<1.5	<3.2	NA
Pioche:					
County courthouse	1/10	24	2.8 ±2.7	8.1 ±3.5	NA
Round Mountain:					
Mobil Service Station	1/9	27	2.8 ±2.5	3.9 ±3.2	NA
Scotty's Junction:					
Holloway Ranch	1/14	23	7.8 ±5.1	12 ±3.7	240 ±230
Springdale:					
Pond	1/8	21	6.8 ±4.7	10 ±3.7	NA

See footnotes at end of table.

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Table 1. Water surveillance results, First Quarter 1974—continued

Location	Date collected (1974)	Sample type[a]	Radionuclide concentrations[b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
Nevada:					
Sunnyside:					
Adam McGill Reservoir	1/16	21	6.2 ±3.7	10 ±3.4	NA
Wildlife Management Headquarters	1/16	27	2.3 ±2.1	<2.9	NA
Tonopah:					
Jerry's Chevron Station	1/8	23	3.9 ±3.2	8.5 ±3.4	NA
Tonopah Test Range CP-1	1/8	23	5.0 ±4.0	7.9 ±3.4	NA
Warm Springs:					
Fallini's Pond	NS				
Service Station and Cafe	1/17	27	13 ±7.3	24 ±4.5	NA
Twin Springs Ranch	1/10	23	20 ±7.3	28 ±4.6	NA
Utah:					
Cedar City:					
M.D. Baldwin residence	1/16	24	<1.4	<2.9	NA
St. George:					
R. Cox Dairy	1/17	24	3.5 ±2.1	<2.9	NA

[a] 21 Pond, lake, reservoir, stock tank, stock pond.
22 Stream, river, creek.
23 Well
24 Multiple supply mixed (a water sample consisting of mixed or multiple sources of water such as well and spring).
27 Spring.

[b] Two-sigma counting error provided when available.
NA, not analyzed.
NS, no sample.

ERAMS Surface and Drinking Water Components
October-December 1973

Office of Radiation Programs
Environmental Protection Agency

The Environmental Radiation Ambient Monitoring System (ERAMS), which began in July 1973, was developed from previously operating radiation monitoring networks to form a single monitoring system which is more responsive to current and projected sources of environmental radiation.

Present network

The ERAMS Surface and Drinking Water Components are an expansion of the previous Tritium Surveillance System which was operated by the Office of Radiation Programs from 1970 through June 1973. The Drinking Water Component consists of 76 quarterly drinking water samples taken from major population centers and selected nuclear facility environs (figure 1). The analyses include (a) tritium on a quarterly basis, (b) gamma scan, gross alpha and gross beta radioactive measurements annually with radium-226 and strontium-90 measurements if the gross alpha or gross beta radio-

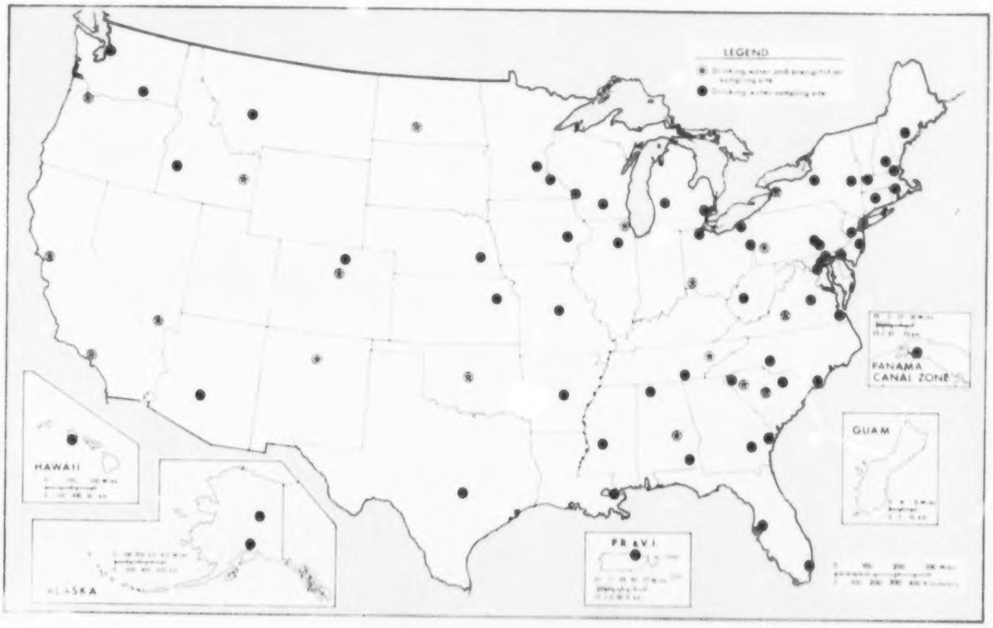
LEGEND
● Drinking water and precipitation sampling site
● Drinking water sampling site
HAWAII
ALASKA
P.R.-V.I.
PANAMA CANAL ZONE
GUAM

Figure 1. ERAMS drinking water component and precipitation sampling locations

activity exceed 3 or 10 pCi/liter, respectively, and (c) an annual composite for plutonium-238 and -239 on 19 selected sampling locations. The Surface Water Component consists of 55 quarterly surface water samples downstream from nuclear facilities or at a background station (figure 2). The location of the sampling sites was based on all nuclear facilities that were operating, being constructed, or planned through 1976. Tritium analyses are performed quarterly and gamma scans annually. In addition to these components of ERAMS, precipitation samples will be collected at 19 selected locations (figure 1) and tritium measurements are performed on the monthly composite from each station. These 19 locations correspond to air and drinking water sampling locations selected for plutonium analyses. Plutonium-238 and -239 analyses are performed annually on precipitation samples collected in April when elevated levels of rainfall are expected.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the Drinking Water Component stations for October–December 1973. The average tritium concentration was 0.3 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalents from tritium in body water have been based on a relationship derived by Moghissi and Porter (*1*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP recommendation (*2*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*3*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*4*) substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$H \text{ (mrem/year)} = 0.1C \text{ (nCi/liter)}$$

Where H is the dose equivalent rate and C represents the tritium concentration in body water in nCi/liter.

It can be assumed for the purpose of calcu-

Table 1. ERAMS Drinking Water Component, October-December 1973

Location		Date collected (1973)	Tritium concentration[a] (nCi/liter ±2σ)[b]
Ala:	Dothan	10/15	0
	Montgomery	10/1	0
	Muscle Shoals	NS	
Alaska:	Anchorage	10/17	.3
	Fairbanks	10/28	.8 ±0.3
Ark:	Little Rock	10/5	0
Calif:	Berkeley	10/9	0
	Los Angeles	10/10	0
C.Z:	Ancon	10/23	.3
Colo:	Denver	10/30	.6
	Platteville	NS	
Conn:	Hartford	10/16	.2
Del:	Wilmington	10/24	.3
D.C:	Washington	11/6	.3
Fla:	Miami	10/5	0
	Tampa	10/29	0
Ga:	Baxley	10/9	0
	Savannah	10/9	7.1 ± .3
Hawaii:	Honolulu	10/16	0
Idaho:	Boise	10/12	.5
	Idaho Falls	10/15	.4
Ill:	Chicago	10/25	.2
	Morris	10/23	0
Iowa:	Palo	NS	
Kans:	Topeka	10/10	0
La:	New Orleans	10/17	.2
Maine:	Augusta	10/12	.3
Md:	Baltimore	10/9	.3
	Conowingo	NS	
Mass:	Lawrence	10/5	.3
	Rowe	10/29	0
Mich:	Detroit	10/1	.6
	Grand Rapids	10/10	0
Minn:	Minneapolis	10/12	.5
	Red Wing	10/31	0
Miss:	Jackson	10/5	0
Mo:	Jefferson City	10/18	0
Mont:	Helena	10/24	.4
Nebr:	Lincoln	10/9	.2
Nev:	Las Vegas	10/10	1.0
N.H:	Concord	10/9	.3
N.J:	Trenton	10/31	0
	Waretown	10/18	0
N. Mex:	Santa Fe	10/29	.4
N.Y:	Albany	10/11	.3
	Buffalo	10/11	.4
	New York City	NS	
	Syracuse	10/30	.5
N.C:	Charlotte	10/18	.4
	Wilmington	10/30	.3
N. Dak:	Bismarck	10/12	.6
Ohio:	Cincinnati	10/9	.4
	East Liverpool	NS	
	Painesville	10/12	.3
	Toledo	NS	
Okla:	Oklahoma City	10/8	0
Oreg:	Portland	NS	
Pa:	Columbia	NS	
	Harrisburg	10/10	.3
	Pittsburgh	NS	
P.R:	San Juan	11/13	0
R.I:	Providence	10/10	0
S.C:	Anderson	10/19	.3
	Columbia	10/4	.2
	Hartsville	10/19	.2
	Seneca	10/19	.4
Tenn:	Chattanooga	10/4	0
	Knoxville	10/5	0
Tex:	Austin	10/9	0
Va:	Doswell	NS	
	Lynchburg	NS	
	Norfolk	NS	
Wash:	Richland	NS	
	Seattle	10/10	.2
Wisc:	Genoa	10/18	0
	Madison	10/9	0
Average			0.3

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

Table 2. ERAMS Surface Water Component, October-December 1973

Location		Water source	Facility	Collection date (1973)	Concentration [a] (nCi/liter ±2σ)[b]
Ala:	Decatur	Tennessee River	Browns Ferry, Sequoyah and Oak Ridge	10/16	0.4
	Gordon	Chattahoochie River	Joseph M. Farley	10/15	0
Ark:	Little Rock	Arkansas River	Arkansas Nuclear One	10/ 5	0
Calif:	Clay Station	Folsom S. Canal	Rancho Seco	NS	
	Diablo Canyon	Pacific Ocean	Diablo Canyon	NS	
	Eureka	Humboldt Bay	Humboldt Bay	NS	
	San Onofre	Pacific Ocean	San Onofre	NS	
Colo:	Greely	South Platte River	Fort St. Vrain	10/30	.8
Conn:	East Haddam	Connecticut River	Haddam Neck and Vermont Yankee	10/26	.5
	Waterford	Long Island Sound	Millstone	10/26	0
Fla:	Crystal River	Gulf of Mexico	Crystal River	NS	
	Ft. Pierce	Atlantic Ocean	St. Lucie	NS	
	Homestead	Biscayne Bay	Turkey Point	NS	
Ga:	Baxley	Altamaha River	Edwin I. Hatch	10/ 9	0
Idaho:	Buhl	Snake River	National Reactor Testing Station	10/11	.5
Ill:	Moline	Mississippi River	Quad-Cities, Genoa, Prairie Island and Monticello	11/ 6	.3
	Morris	Illinois River	Dresden and Argonne	10/23	.3
	Zion	Lake Michigan	Zion	10/26	.3
Iowa:	Palo	Cedar River	Duane Arnold	NS	
La:	New Orleans	Mississippi River	(Several)	10/ 5	0
Maine:	Wiscasset	Montseway Bay	Maine Yankee	10/ 9	.4
Md:	Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	10/16	.4
	Lusby	Chesapeake Bay	Calvert Cliffs	10/23	.3
Mass:	Plymouth	Plymouth Bay	Pilgrim	10/10	.3
	Rowe	Deerfield River	Yankee	10/ 8	4.7 ±0.3
Mich:	Bridgman	Lake Michigan	Donald C. Cook	10/ 9	.4
	Charlevoix	Lake Michigan	Big Rock Point	10/ 7	.3
	Monroe	Lake Erie	Enrico Fermi	10/ 8	.3
	South Haven	Lake Michigan	Palisades	10/ 9	.3
Minn:	Monticello	Mississippi River	Monticello	10/ 4	.6
	Red Wing	Mississippi River	Prairie Island and Monticello	10/31	.4
Nebr:	Rulo	Missouri River	Fort Calhoun & Cooper	10/18	.3
Nev:	Boulder City	Colorado River	Background	10/ 4	.7
N.J:	Bayside	Delaware River	Salem	10/18	.2
	Oyster Creek	Toms River	Oyster Creek	10/18	0
N.Y:	Ossining	Hudson River	Indina Point	10/12	.4
	Oswego	Lake Ontario	Nine Mile Point, James A. Fitzpatrick and R. E. Ginna	10/ 3	.5
	Poughkeepsie	Hudson River	Background	10/ 3	0
N.C:	Charlotte	Catawba River	Wm. B. McGuire	10/18	.3
	Southport	Atlantic Ocean	Brunswick	10/ 1	0
Ohio:	Oak Harbor	Lake Erie	Davis-Besse	NS	
Oreg:	Westport	Columbia River	Trojan and Hanford	NS	
S.C:	Allendale	Savannah River	Savannah River Plant and Oconee	10/25	9.4 ± .4
	Hartsville	Lake Robinson	H. B. Robinson	10/19	0
Tenn:	Daisy	Tennessee River	Sequoyah and Oak Ridge	11/14	0
	Kingston	Clinch River	Oak Ridge	10/ 5	2.4 ± .3
Tex:	El Paso	Rio Grande	Los Alamos	10/ 4	.3
Vt:	Vernon	Connecticut River	Vermont Yankee	10/ 4	.2
Va:	Mineral	North Anna River	North Anna	NS	
	Newport News	James River	Surry	10/ 2	0
Wash:	Northport	Columbia River	Background	11/24	.8
	Richland	Columbia River	Hanford	10/ 1	.6
W. Va:	Wheeling	Ohio River	Shippingport and Beaver Valley	10/ 9	0
Wisc:	Two Creeks	Lake Michigan	Point Beach and Kewaunee	10/ 8	.3
	Victory	Mississippi River	Genoa, Prairie Island and Monticello	10/ 8	.4
Average					0.5

[a] The minimum detection limit for all samples in 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

lating dose to members of the population that if the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also if that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in drinking water was 7.1 nCi/liter during the fourth quarter. This corresponds to a dose of 0.7 mrem/a.

The tritium concentrations for the Surface Water Component samples are given in table 2. The highest tritium concentration was 9.4 nCi/liter for the quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.9 mrem/a.

The monthly analyses for tritium in precipi-

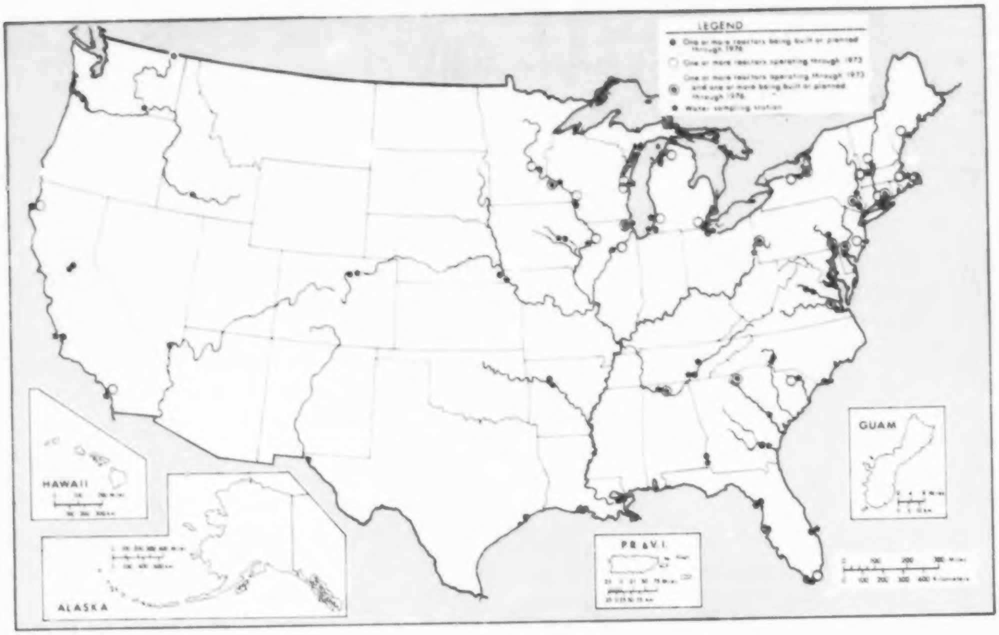
LEGEND
One or more reactors being built or planned through 1976
One or more reactors operating through 1973
One or more reactors operating through 1973 and one or more being built or planned through 1976
Water sampling station
HAWAII
ALASKA
PR & V.I.
GUAM

Figure 2. ERAMS surface water component sampling stations

tation samples at the selected stations are shown in table 3.

Table 3. Tritium concentration in precipitation October-December 1973

Location		Tritium concentration[a] (nCi/liter ±2σ)		
		October	November	December
Ala:	Montgomery	0	0.5	0.4
Calif:	Berkeley	0	0	.2
	Los Angeles	NS	NS	NS
Colo:	Denver	0	.3	0
Idaho:	Idaho Falls	NS	NS	NS
Ill:	Chicago	NS	NS	NS
Nev:	Las Vegas	NS	NS	NS
N.Mex:	Santa Fe	NS	NS	NS
N.Y:	Buffalo	NS	.4	0
	New York City	NS	NS	NS
N. Dak:	Bismarck	0	0	0
Ohio:	Cincinnati	NS	NS	NS
Okla:	Oklahoma City	NS	NS	NS
Oreg:	Portland	NS	NS	NS
Pa:	Pittsburgh	NS	NS	NS
S.C:	Anderson	NS	NS	NS
	Columbia	.3	.7	.4
Tenn:	Knoxville	NS	NS	NS
Va:	Lynchburg	NS	NS	NS

[a] The minimum detection limit for these samples was 0.20 nCi/liter All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

NS, no sample.

Other coverage in *Radiation Data and Reports:*

Period	Issue
October–December 1972	May 1973
January–March 1973	July 1973
April–June 1973	October 1973
July–September 1973	May 1974

REFERENCES

(1) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(2) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965), ICRP Publication 9 (1969).

(3) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Basic radiation protection criteria, NCRP Report No. 39. National Council on Radiation Protection and Measurements, Washington, D.C. 20008 (January 15, 1971).

(4) INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS. Radiation quantities and units, ICRU Report No. 19. International Commission on Radiation Units and Measurements, Washington, D.C. 20014 (July 1972).

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Radioactivity in New York State Surface Water January-December 1972

Bureau of Radiological Pollution Control
N.Y.S. Department of Environmental
Conservation

In 1955, New York State began a program to determine the amount of radioactivity in water used for public consumption. Radioactivity in water may arise from any one or a combination of the following sources: the natural mineral content of water (background), atmospheric fallout, or nuclear industry operations.

Analytical procedures

Analysis of samples was performed by the Radiological Sciences Laboratory of the New York State Department of Health. The procedures described below were used to perform the indicated analyses.

A gross beta determination is made on a measured quantity of water, usually 250 ml. The sample residue is analyzed for its gross beta component in an end window, gas-flow proportional counter.

Strontium and alkaline earths are precipitated as carbonates from a 1-liter sample. The strontium fraction is separated from calcium and barium by ion exchange separation on AG 50W–x8 from EDTA solution and subsequent elution with 1.5 HCl. The eluate is evaporated to dryness, taken up in water and $SrNO_3$ precipitated. Strontium is reprecipitated as $SrCO_3$ for gravimetric determination of recovery, then redissolved and held for yttrium-90 ingrowth.

Following yttrium-90 ingrowth, yttrium is precipitated as the hydroxide, purified by TBP extraction and back-extracted into water, reprecipitated, weighed and counted as Y_2O_3. Strontium is precipitated as the carbonate from

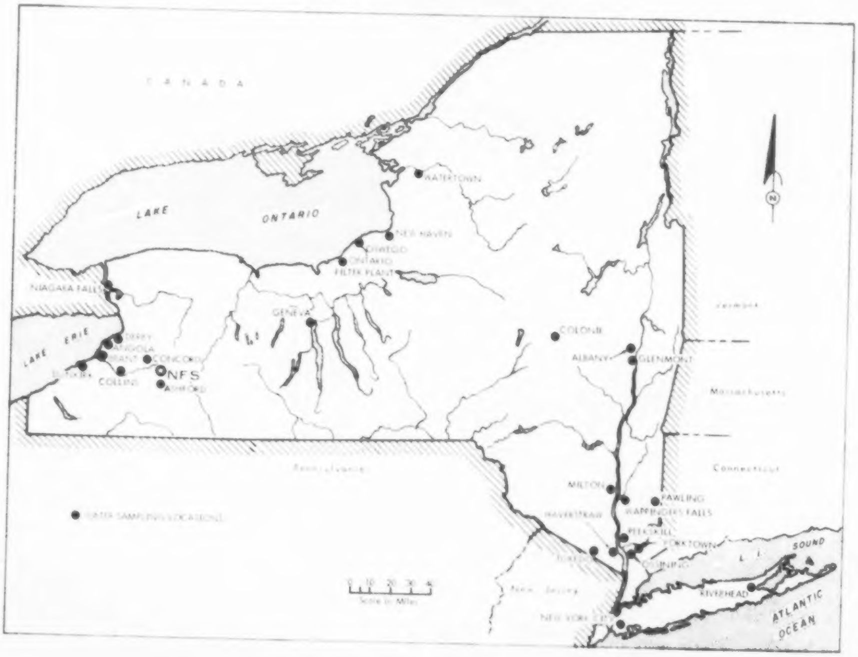
CANADA
LAKE ONTARIO
LAKE ERIE
WATERTOWN
NEW HAVEN
OSWEGO
ONTARIO FILTER PLANT
NIAGARA FALLS
GENEVA
DERBY
ANGOLA
BRANT
CONCORD
DUNKIRK
COLLINS
NFS
ASHFORD
COLONIE
ALBANY
GLENMONT
Vermont
Massachusetts
Connecticut
Pennsylvania
MILTON
PAWLING
HAVERSTRAW
WAPPINGERS FALLS
PEEKSKILL
YORKTOWN
OSSINING
New Jersey
NEW YORK CITY
RIVERHEAD
L. I. SOUND
ATLANTIC OCEAN
N
Scale in Miles
WATER SAMPLING LOCATIONS

Figure 1. New York water sampling locations

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Table 1. Gross beta radioactivity in New York surface waters,[a] January-December 1972

Location	Gross beta radioactivity (pCi/liter)							
	January-March 1972				April-June 1972			
	Number of Samples	Average	Maximum	Minimum	Number of Samples	Average	Maximum	Minimum
Albany	3	3	3	2	3	2	3	2
Angola (Angola Water Treatment Plant)	13	7	12	5	11	7	9	5
Ashford (Buttermilk Creek at Fox Valley Road)	3	5	6	5	3	3	6	ND
(Buttermilk Creek at Thomas Corners)[b]	13	1 434	5 447	198	13	1 307	3 172	185
(Cattaraugus Creek at Bigelow Bridge)	3	6	14	ND	4	20	77	ND
Colonie (Filtration Plant)	13	5	10	2	13	4	6	3
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	146	266	60	13	117	180	17
Daily continuous sample	63	140	840	46	64	122	628	11
Derby (Sturgeon Point)	12	6	8	4	13	6	13	ND
Dunkirk (Dunkirk Filtration Plant)	13	5	7	3	13	4	7	ND
Geneva (Seneca Lake)	3	4	6	3	3	7	8	5
Glenmont (Hudson River)	13	3	5	ND	12	4	6	3
Haverstraw (Iona Filtration Gallery)	1	6			1	2		
Milton (Glowegee Creek at Rt. 50)	4	2	3	2	2	5	5	4
New Haven (Demster Beach Road)	2	5	5	4	2	5	5	4
New York City	6	4	5	2	5	3	6	2
Niagara Falls (West Branch Niagara River)	5	4	5	3	3	4	4	4
Ontario (Ontario Filtration Plant)	14	5	6	3	11	4	6	ND
Ossining (Hudson River at Sing Sing)	15	12	32	ND	13	6	27	3
(Indian Brook Reservoir-raw)	3	4	4	3	3	4	5	3
(Indian Brook Reservoir-treated)	3	4	4	3	3	4	4	3
Oswego (City Hall tap)	7	4	6	3	6	3	5	ND
Pawling (Pond at United Nuclear)	5	3	4	2	3	5	5	4
Peekskill (Camp Field Filter Plant-raw)	3	4	5	3	3	4	5	3
(Camp Field Filter Plant-treated)	3	2	3	ND	3	3	3	2
(Hudson River at Standard Brands)	15	5	15	ND	12	4	16	ND
Rhinecliff (Hudson River)	11	3	6	2	12	3	7	ND
Riverhead (Peconic River)	3	4	5	2	3	4	5	3
Tuxedo (Indian Kill, 150 feet below reservoir)	3	5	5	4	3	4	6	3
Wappinger (Hudson River)	11	4	7	2	12	4	9	ND
Watertown (Black River)	3	3	3	2	3	4	5	3
Yorktown (Croton Reservoir—inlet)	3	3	3	2	3	6	6	5
(Croton Reservoir-deep water)	3	3	4	3	3	4	5	3

Location	July-September 1972				October-December 1972			
	Number of Samples	Average	Maximum	Minimum	Number of Samples	Average	Maximum	Minimum
Albany	3	3	5	2	3	2	2	2
Angola (Angola Water Treatment Plant)	14	5	10	3	11	5	6	2
Ashford (Buttermilk Creek at Fox Valley Road)	3	2	5	ND	3	5	6	4
(Buttermilk Creek at Thomas Corners)[b]	13	4 226	10 592	1 590	13	612	1 670	52
(Cattaraugus Creek at Bigelow Bridge)	3	8	16	ND	3	5	7	2
Colonie (Filtration Plant)	13	4	7	3	13	3	6	2
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	329	620	151	13	86	193	14
Daily continuous sample	63	322	714	120	60	81	240	9
Derby (Sturgeon Point)	13	5	6	4	10	5	6	3
Dunkirk (Dunkirk Filtration Plant)	13	4	7	2	11	4	6	3
Geneva (Seneca Lake)	3	5	9	ND	3	3	5	ND
Glenmont (Hudson River)	11	3	4	2	12	4	6	2
Haverstraw (Iona Filtration Gallery)	NS				NS			
Manorville (Peconic River)	NS				3	10	12	7
Milton (Glowegee Creek at Rt. 50)	2	3	3	2	3	3	4	2
New Haven (Demster Beach Road)	3	4	4	4	3	5	6	5
New York City	5	4	5	3	4	2	3	ND
Niagara Falls (West Branch Niagara River)	3	4	5	3	2	4	4	3
Ontario (Ontario Filtration Plant)	13	4	6	3	12	4	8	2
Ossining (Hudson River at Sing Sing)	13	23	66	ND	12	21	68	ND
(Indian Brook Reservoir-raw)	3	4	5	3	3	4	4	3
(Indian Brook Reservoir-treated)	3	3	4	3	3	3	3	2
Oswego (City Hall tap)	6	4	5	3	6	4	5	3
Pawling (Pond at United Nuclear)	1	2			NS			
Peekskill (Camp Field Filter Plant-raw)	3	3	4	3	3	2	3	2
(Camp Field Filter Plant-treated)	3	3	3	2	3	2	3	2
(Hudson River at Standard Brands)	11	14	57	2	12	11	32	ND
Rhinecliff (Hudson River)	13	4	16	ND	12	4	11	ND
Riverhead (Peconic River)	3	6	8	4	NS			
Tuxedo (Indian Kill, 150 feet below reservoir)	3	3	5	2	3	2	3	2
Wappinger (Hudson River)	13	2	5	ND	12	4	15	ND
Watertown (Black River)	3	3	4	2	2	3	3	3
Yorktown (Croton Reservoir inlet)	3	3	6	2	3	3	3	3
(Croton Reservoir-deep water)	3	2	2	2	3	3	4	3

[a] Excluding tritium.

[b] This station is on the Nuclear Fuels Services reprocessing plant site.

ND, nondetectable.

NS, no sample

Table 2. Strontium concentration of New York surface waters, January-December 1972

Location	Strontium-89 (pCi/liter)				Strontium-90 (pCi/liter)			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Ashford (Buttermilk Creek at Thomas Corners Road)	NS				52	95	357	ND
(Cattaraugus Creek at Bigelow Bridge)	NS				13	ND	8	ND
Concord (Cattaraugus Creek at Springville Dam-weekly composite sample)	NS				52	9	47	ND
(Cattaraugus Creek at Springville Dam-daily continuous sample)	1	ND			33	13	55	ND
New Haven (Demster Beach Road)	NS				1	ND		
Niagara Falls (West Branch of Niagara River)	2	ND	ND	ND	2	ND	ND	ND
Ossining (Hudson River at Sing Sing)	12	ND	ND	ND	53	ND	5	ND
Peekskill (Hudson River at Standard Brands)	12	ND	ND	ND	50	ND	4	ND

NS, no sample.
ND, nondetectable.

the ingrowth solution, reprecipitated as $SrSO_4$, weighed and counted. The strontium-90 activity is calculated from a least squares fit of the yttrium-90 decay data. The strontium-89 activity is determined by subtraction of strontium-90 and yttrium-90 activity from the total strontium-90 activity following appropriate efficiency corrections. If strontium-90 only is required, the ion exchange step is omitted and the recovery determined radiometrically using strontium-89 spike.

Chemical recovery is between 70 and 75 percent and results in a minimum detectable activity for strontium-90 of 1 pCi/liter ± 100 percent at the 95 percent confidence level. The strontium-90 detection limit varies according to the strontium-89/strontium-90 activity ratio, but generally approaches 3 pCi/liter ± 100 percent.

Tritium in water is determined by liquid scintillation counting. The vacuum distillation separates tritium from other interfering radionuclides and removes chemical and/or physical quenching agents. An aliquot of the distillate is mixed with an organic scintillator and counted for 50 minutes in a liquid scintillation spectrometer. Water known to be of low tritium content is used as a background sample. The degree of quenching in a sample is determined by an external standardization source.

The quench factor is used to determine the counting efficiency and the tritium activity in the sample calculated. Analysis of a 10 ml aliquot of the distillate results in a sensitivity of approximately 500 pCi/liter. The sensitivity of the method is defined as that value at which the error at the 95 percent confidence limit equals the measured value, i.e., 100 percent error.

Discussion and results

The concentrations of radionuclides in most water samples throughout the State were low with exception of the water immediately downstream of the Nuclear Fuel Services fuel reprocessing plant (NFS) discharge (figure 1).

Two daily samples from Cattaraugus Creek at Springville Dam, Site 042 exceeded 600 pCi/liter of gross beta radioactivity which is considered to be the allowable AEC limit for a single sample without making a specific isotopic analysis.

The number of samples, quarterly average, maximum and minimum gross beta and strontium concentrations in New York surface water for January–December 1972 are given in tables 1 and 2.

Tritium concentration values for January–December 1972 are given in table 3. Tritium, the radioactive isotope of hydrogen, a very low energy beta-particle emitter, is released to the water courses during the reprocessing of nuclear fuel. The tritium concentrations in Cat-

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Table 3. Tritium concentrations of New York surface waters, January-December 1972

Location	Tritium concentration (pCi/liter)							
	January-March 1972				April-June 1972			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Albany	3	ND	ND	ND	3	ND	ND	ND
Angola (Angola Water Treatment Plant)	4	ND	ND	ND	3	ND	ND	ND
Ashford (Buttermilk Creek at Fox Valley Road)	3	ND	ND	ND	3	ND	ND	ND
(Buttermilk Creek at Thomas Corners)[a]	13	24.7	90.2	4.7	13	26.6	89.1	ND
(Cattaraugus Creek at Bigelow Bridge)	3	ND	ND	ND	4	ND	ND	ND
Colonie (Filtration Plant)	3	ND	.6	ND	3	ND	ND	ND
Concord (Cattaragus Creek at Springville Dam):								
Weekly composite sample	13	3.2	5.5	1.2	13	2.1	4.8	ND
Daily continuous sample	63	3.2	9.1	ND	64	2.2	12.7	.5
Derby (Sturgeon Point)	3	ND	ND	ND	4	ND	ND	ND
Dunkirk (Dunkirk Filtration Plant)	3	ND	ND	ND	4	ND	ND	ND
Geneva (Seneca Lake)	3	ND	.7	ND	3	ND	ND	ND
Milton (Glowegee Creek at Rt. 50)	4	ND	ND	ND	2	ND	ND	ND
New Haven (Demster Beach Road)	2	ND	ND	ND	2	ND	ND	ND
Ontario (Ontario filter plant)	14	ND	ND	ND	10	ND	.9	ND
Ossining (Hudson River at Sing Sing)	3	ND	ND	ND	2	ND	ND	ND
Oswego (City Hall tap)	4	ND	ND	ND	3	ND	.7	ND
Pawling (pond at United Nuclear Corp.)	NS				2	ND	ND	ND
Peekskill (Hudson River at Standard Brands)	4	ND	ND	ND	3	ND	ND	ND
Rhinecliff (Hudson River)	11	ND	ND	ND	12	ND	ND	ND
Riverhead (Peconic River)	3	ND	ND	ND	3	ND	ND	ND
Tuxedo (Indian Kill, 150 feet below Reservoir)	3	ND	ND	ND	3	ND	ND	ND
Wappinger (Hudson River)	10	ND	ND	ND	13	ND	.6	ND

Location	July-September 1972				October-December 1972			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Albany	3	ND	ND	ND	3	ND	ND	ND
Angola (Angola Water Treatment Plant)	3	ND	ND	ND	2	ND	ND	ND
Ashford (Buttermilk Creek at Fox Valley Road)	3	NS	ND	ND	3	ND	ND	ND
(Buttermilk Creek at Thomas Corners)[a]	13	30.1	73	6.8	13	9.9	40	ND
(Cattaraugus Creek at Bigelow Bridge)	3	ND	ND	ND	3	ND	ND	ND
Colonie (Filtration Plant)	4	ND	ND	ND	3	ND	ND	ND
Concord (Cattaraugus Creek at Springville Dam):								
Weekly composite sample	13	2.3	5.7	ND	13	1.1	3.6	ND
Daily continuous sample	63	2.4	6.6	ND	60	1.1	5.6	ND
Derby (Sturgeon Point)	3	ND	ND	ND	2	ND	ND	ND
Dunkirk (Dunkirk Filtration Plant)	3	ND	.7	ND	2	ND	ND	ND
Geneva (Seneca Lake)	3	ND	ND	ND	3	ND	ND	ND
Manorville (Peconic River)	NS				3	4.4	5.9	2.2
Milton (Glowegee Creek at Rt. 50)	2	ND	ND	ND	3	ND	ND	ND
New Haven (Demster Beach Road)	3	ND	ND	ND	2	ND	ND	ND
Ontario (Ontario filter plant)	12	ND	.8	ND	12	ND	ND	ND
Ossining (Hudson River at Sing Sing)	4	ND	ND	ND	2	ND	ND	ND
Oswego (City Hall tap)	3	ND	.9	ND	3	ND	.7	ND
Peekskill (Hudson River at Standard Brands)	2	ND	ND	ND	3	ND	ND	ND
Rhinecliff (Hudson River)	13	ND	.8	ND	12	ND	ND	ND
Riverhead (Peconic River)	3	.6	1.9	ND	NS			
Tuxedo (Indian Kill, 150 feet below Reservoir)	3	ND	ND	ND	3	ND	ND	ND
Wappinger (Hudson River)	13	ND	.9	ND	12	ND	ND	ND

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[a] This station is on the Nuclear Fuels Services reprocessing plant site.
ND, nondetectable.
NS, no sample.

taraugus and Buttermilk Creeks reflected contributions to the streams from the Nuclear Fuels Services reprocessing plant.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
July–December 1971	August 1973

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Krypton-85 in air	July 1970–1972	March 1974
Mexican air monitoring	July–December 1973	May 1974
Plutonium in airborne particulates	January–March 1973	May 1974
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network
January 1974

Eastern Environmental Radiation Facility, Montgomery, Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during January 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

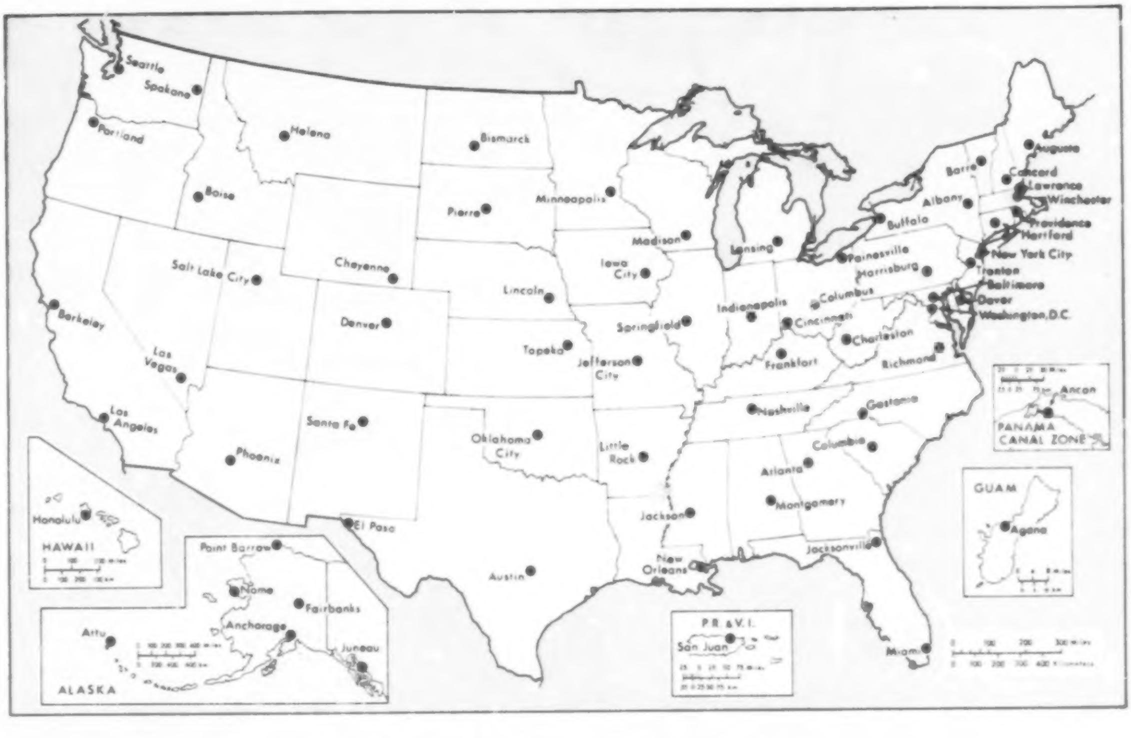
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Madison
Lansing
Iowa City
Berkeley
Lincoln
Denver
Las Vegas
Topeka
Jefferson City
Springfield
Indianapolis
Columbus
Cincinnati
Frankfort
Charleston
Richmond
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Phoenix
Montgomery
Jackson
El Paso
Austin
New Orleans
Jacksonville
Miami
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Attu
Juneau
ALASKA
P.R. & V.I.
San Juan
GUAM
Agana
Ancon
PANAMA CANAL ZONE
Augusta
Barre
Concord
Lawrence
Winchester
Providence
Hartford
Albany
Buffalo
Painesville
Harrisburg
New York City
Trenton
Baltimore
Dover
Washington, D.C.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, January 1974

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	10	1	0	1	0.04	0.02	0.03	127	0.79
Alaska:	Anchorage	3	----	----	----	.04	.03	.03	----	----
Calif:	Berkeley	9	0	0	0	.06	.02	.04	24	.07
	Los Angeles	9	1	0	1	.11	.02	.06	----	----
Colo:	Denver	9	1	0	0	.10	.05	.07	18	.56
Idaho:	Idaho Falls	8	----	----	----	.09	.02	.05	12	.12
Ind:	Indianapolis	6	3	1	2	.05	.03	.04	----	----
Nev:	Las Vegas	9	2	0	1	.09	.02	.05	----	----
N. Mex:	Santa Fe	6	0	0	0	.08	.04	.07	9	.03
N.Y:	Buffalo	9	0	0	0	.17	.02	.05	2	.02
N. Dak:	Bismarck	11	7	0	1	.05	.03	.04	4	.10
Ohio:	Columbus	9	0	0	0	.08	.03	.05	----	----
Okla:	Oklahoma City	1	0	0	0	.04	.04	.04	----	----
Oreg:	Portland	22	0	0	0	.06	<.01	.03	----	----
Pa:	Harrisburg	19	1	0	0	.07	.02	.04	----	----
S.C:	Columbia	8	0	0	0	.09	.02	.05	140	.46
Tex:	Austin	3	4	2	3	.21	.01	.09	----	----
Network summary		151	7	0	1	0.21	<0.01	0.05	42	0.27

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network, January 1974

National Environmental Research Center—Las Vegas,[1] Environmental Protection Agency

The Air Surveillance Network,[2] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 72 standby sampling stations located in 21 Western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radio-activity from the NTS. A complete description of sampling and analytical procedures was presented in the February issue of *Radiation Data and Reports.*

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to one significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to two significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (~0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

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[1] Formerly the Western Environmental Research Laboratory.

[2] This network is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

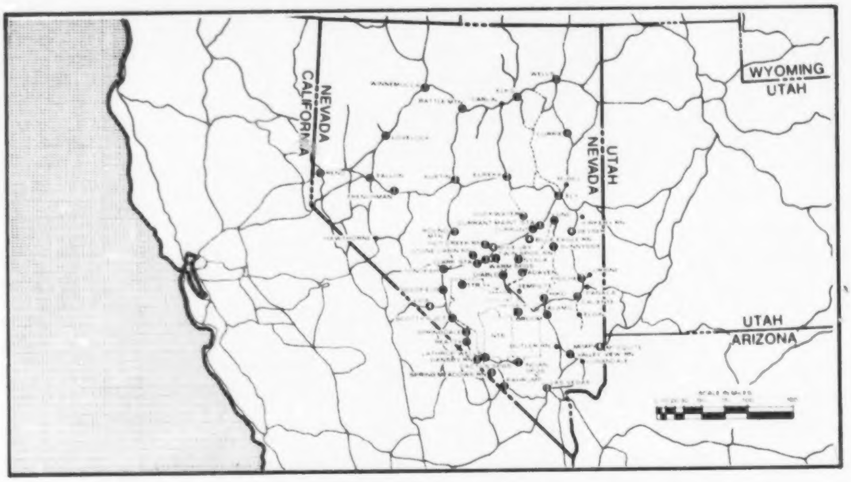
WYOMING
UTAH
NEVADA
CALIFORNIA
UTAH
NEVADA
UTAH
ARIZONA

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

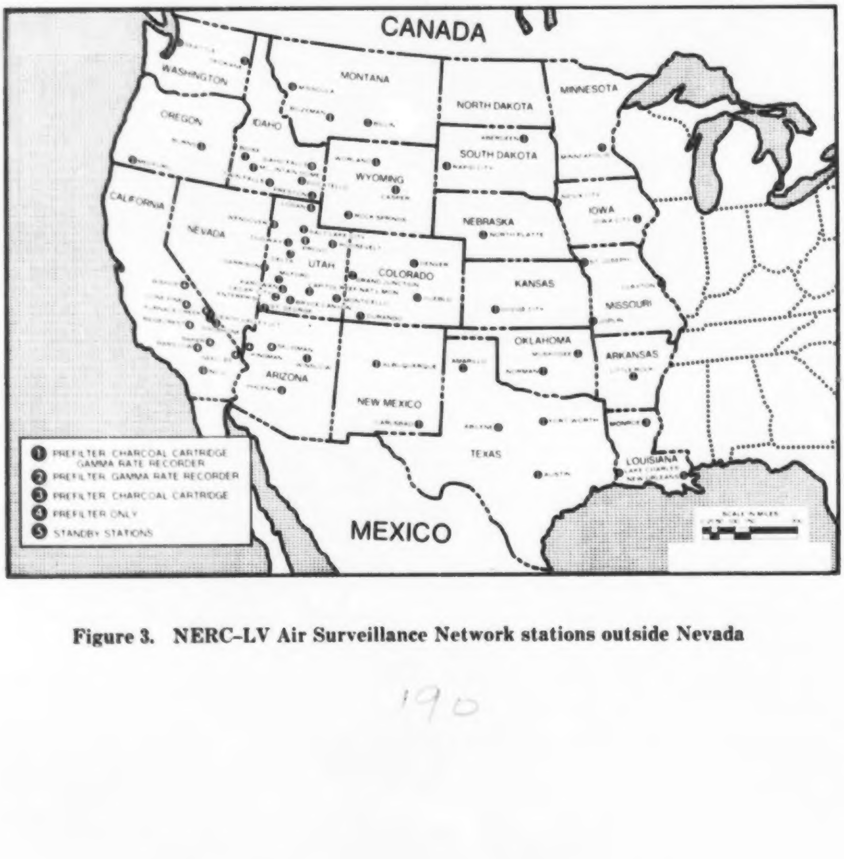
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
SOUTH DAKOTA
WYOMING
IOWA
NEBRASKA
CALIFORNIA
NEVADA
UTAH
COLORADO
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
ARIZONA
NEW MEXICO
TEXAS
LOUISIANA
MEXICO
1 PREFILTER, CHARCOAL CARTRIDGE GAMMA RATE RECORDER
2 PREFILTER, GAMMA RATE RECORDER
3 PREFILTER, CHARCOAL CARTRIDGE
4 PREFILTER ONLY
5 STANDBY STATIONS
SCALE IN MILES

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥ 0.05 <0.15	0.1	<0.1
≥ 0.15	As calculated and rounded	<calculated MDC

As shown in table 2, the highest gross beta concentration at continuously operated stations within the network was 0.3 pCi/m^3 at Bishop, Furnace Creek and Ridgecrest, Calif. and Pahrump, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during January 1974.

The 72 standby stations were activated on January 14 for 1 week of operation to check equipment and gather background radiation data.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 1. Summary of gross beta radioactivity concentration in air, January 1974

Location		Number of samples	Concentration (pCi/m^3)		
			Maximum	Minimum	Average
Ariz:	Kingman	13	0.2	<0.1	0.1
	Phoenix	3	.2	<.1	.1
	Seligman	13	.2	<.1	.1
	Winslow	3	.2	.1	.1
Ark:	Little Rock	3	<.1	<.1	<.1
Calif:	Baker	13	.2	<.1	.1
	Barstow	13	.2	<.1	.1
	Bishop	13	.3	<.1	.2
	Death Valley Junction	13	.2	<.1	.1
	Furnace Creek	13	.3	<.1	.1
	Indio	3	.1	<.1	.1
	Lone Pine	9	.2	<.1	.1
	Needles	10	.2	<.1	.1
	Ridgecrest	13	.3	<.1	.1
	Shoshone	13	.2	<.1	.1
Colo:	Denver	3	.2	.1	.1
	Durango	2	.2	.1	.2
Idaho:	Boise	3	.1	.1	.1
	Idaho Falls	3	.1	<.1	.1
	Preston	2	.1	.1	.1
	Twin Falls	3	.1	.1	.1
Iowa:	Iowa City	3	.1	.1	.1
	Sioux City	3	.2	<.1	.1
La:	Lake Charles	3	.1	.1	.1
	Monroe	3	.1	<.1	.1
	New Orleans	3	.1	<.1	.1
Minn:	Minneapolis	3	.1	.1	.1
Mo:	Clayton	3	.1	.1	.1
	Joplin	3	.1	.1	.1
	St. Joseph	3	.1	<.1	.1
Nebr:	North Platte	3	.2	<.1	.1
Nev:	Alamo	13	.2	<.1	.1
	Austin	11	.1	<.1	.1
	Battle Mountain	1	<.1	<.1	<.1
	Beatty	13	.2	<.1	.1
	Blue Eagle Ranch (Currant)	13	.2	<.1	.1
	Blue Jay	13	.2	<.1	.1
	Caliente	13	.2	<.1	.1
	Currant Ranch	13	.2	<.1	.1
	Currie	3	.1	.1	.1
	Diablo	13	.2	<.1	.1
	Duckwater	13	.2	<.1	.1
	Elko	3	.1	.1	.1
	Ely	13	.2	<.1	.1
	Eureka	13	.2	<.1	.1
	Fallini's Twin Springs Ranch	13	.2	<.1	.1
	Fallon	3	.2	<.1	.1
	Frenchman Station	3	.2	<.1	.1
	Geyser Ranch (Pioche)	11	.2	<.1	.1
	Goldfield	13	.1	<.1	.1
	Groom Lake	12	.2	<.1	.1
	Hiko	13	.2	<.1	.1
	Indian Springs	13	.2	<.1	.1

Table 1. Summary of gross beta radioactivity concentration in air, January 1974—continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average
Nev:	Las Vegas	22	.2	<.1	.1
	Lathrop Wells	12	.1	<.1	.1
	Lida	13	.2	<.1	.1
	Locklock	3	.2	<.1	.1
	Lund	13	.2	<.1	.1
	Mesquite	13	.2	<.1	.1
	Nyala	11	.2	<.1	.1
	Pahrump	14	.3	<.1	.1
	Pioche	13	.2	<.1	.1
	Reno	3	.1	.1	.1
	Round Mountain	13	.2	<.1	.1
	Scotty's Junction	12	.2	<.1	.1
	Stone Cabin Ranch	13	.2	<.1	.1
	Sunnyside	13	.1	<.1	.1
	Tonopah	13	.2	<.1	.1
	Tonopah Test Range	11	.2	<.1	.1
	Warm Springs	11	.2	<.1	.1
	Warm Springs Ranch	13	.2	<.1	.1
	Wells	3	.2	.1	.1
	Winnemucca	3	.1	<.1	.1
N. Mex:	Albuquerque	3	.2	<.1	.1
	Carlsbad	2	.3	.2	.2
Okla:	Muskogee	6	.1	<.1	.1
Oreg:	Burns	5	.1	<.1	.1
	Medford	3	.1	<.1	.1
S. Dak	Aberdeen	3	.1	<.1	.1
	Rapid City	3	.1	<.1	.1
Tex:	Abilene	3	.2	.1	.1
	Austin	3	.1	<.1	<.1
	Fort Worth	3	.1	.1	.1
Utah:	Bryce Canyon	3	.1	<.1	.1
	Cedar City	10	.2	<.1	.1
	Delta	8	.2	<.1	.1
	Dugway	3	.2	.1	.2
	Enterprise	3	.2	.1	.2
	Garrison	13	.2	<.1	.1
	Logan	3	.2	.1	.1
	Milford	10	.2	<.1	.1
	Monticello	3	.1	<.1	.1
	Parowan	3	.2	.1	.2
	Provo	3	.1	.1	.1
	Salt Lake City	3	.2	<.1	.1
	St. George	14	.1	<.1	.1
Wash:	Seattle	3	<.1	<.1	<.1
	Spokane	3	.1	<.1	.1
Wyo:	Rock Springs	3	.1	<.1	.1

3. Canadian Air and Precipitation Monitoring Program,[3] January 1974

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May

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[3] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

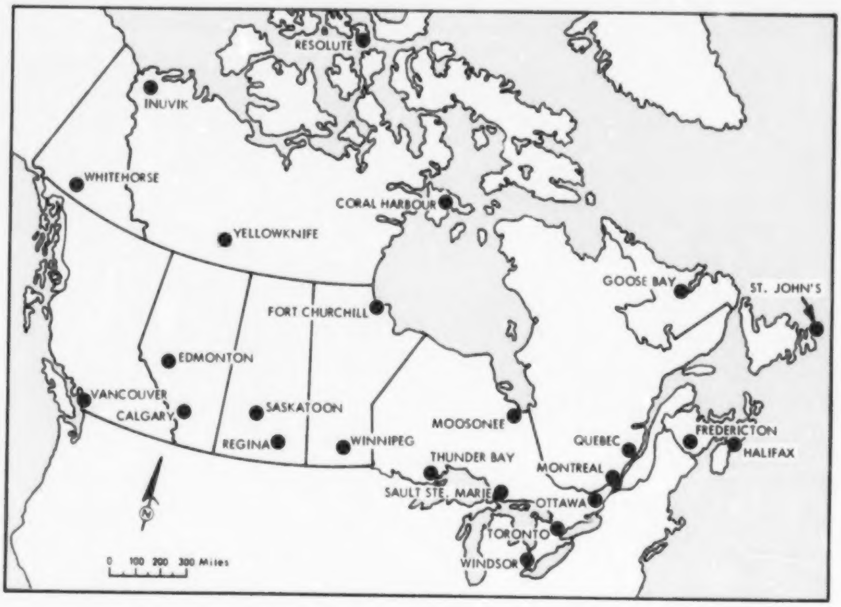
RESOLUTE
INUVIK
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
THUNDER BAY
MONTREAL
SAULT STE. MARIE
OTTAWA
TORONTO
WINDSOR
N
0 100 200 300 Miles

Figure 4. Canadian air and precipitation monitoring program

Table 3. Canadian gross beta radioactivity in surface air and precipitation, January 1974

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.03	0.02	0.03	16.3	0.4
Coral Harbour	5	.05	.04	.05	34.0	.2
Edmonton	5	.05	.03	.04	9.8	.3
Ft. Churchill	4	.05	.01	.03	26.0	.2
Fredericton	5	.03	.03	.03	15.5	1.3
Goose Bay	4	.03	.01	.02	14.8	.3
Halifax	5	.04	.03	.04	11.5	1.1
Inuvik	5	.06	.02	.04	7.9	.3
Montreal	5	.03	.02	.03	14.9	1.0
Moosonee	4	.05	.04	.05	5.8	.3
Ottawa	5	.04	.02	.03	10.2	.6
Quebec	5	.03	.02	.03	9.6	.9
Regina	5	.05	.03	.04	12.1	.4
Resolute	5	.05	.02	.04	NS	NS
St. John's, Nfld	5	.02	.01	.02	NS	NS
Saskatoon	5	.05	.03	.04	7.1	.3
Sault Ste. Marie	5	.04	.02	.03	22.6	1.6
Thunder Bay	4	.04	.03	.04	11.9	.4
Toronto	NS				18.1	1.2
Vancouver	4	.02	.01	.02	11.8	2.1
Whitehorse	5	.05	.03	.04	NS	NS
Windsor	NS				13.6	1.1
Winnipeg	3	.05	.01	.03	8.0	.3
Yellowknife	4	.04	.01	.03	NS	NS
Network summary	102	0.06	0.01	0.04	14.1	0.5

NS, no sample.

1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for January 1974 are presented in table 3.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

4. Pan American Air Sampling Program
January 1974

Pan American Health Organization and
U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The January 1974 air monitoring results from the participating countries are given in table 4.

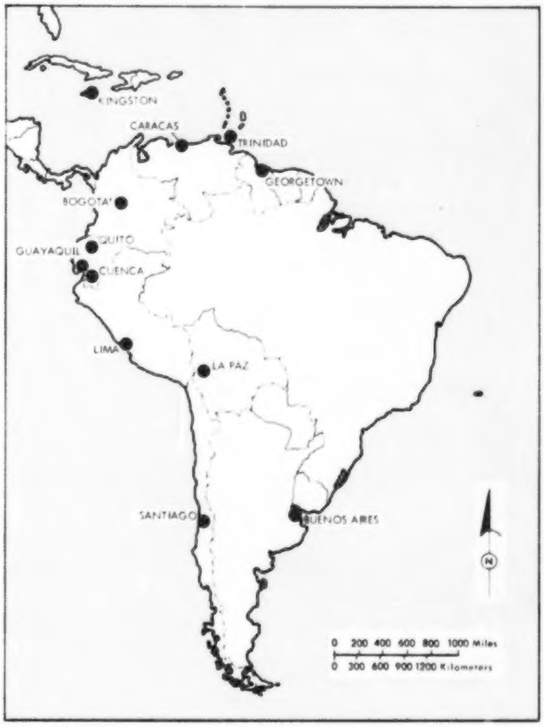

Figure 5. Pan American Air Sampling Program stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, January 1974

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	0			
Chile:	Santiago	0			
Colombia:	Bogota	22	0.04	0.00	0.02
Ecuador:	Cuenca	17	.04	.00	.01
	Guayaquil	20	.04	.00	.01
	Quito	11	.01	.00	.00
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	10	.02	.00	.01
Trinidad and Tobago:	Port of Spain	0			
Venezuela:	Caracas	16	.13	.00	.02
Pan American summary		96	0.13	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

5. California Air Sampling Program
January 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similar equipment in nearby communities and at several "background" stations.[1]

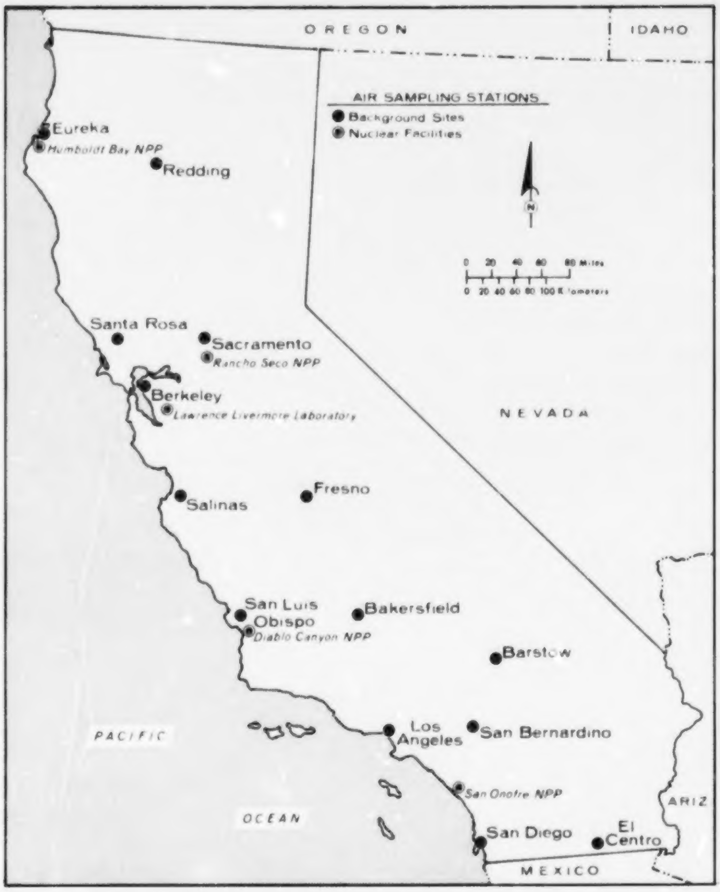
OREGON
IDAHO
AIR SAMPLING STATIONS
● Background Sites
● Nuclear Facilities
N
0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Eureka
Humboldt Bay NPP
Redding
Santa Rosa
Sacramento
Rancho Seco NPP
Berkeley
Lawrence Livermore Laboratory
NEVADA
Fresno
Salinas
San Luis Obispo
Diablo Canyon NPP
Bakersfield
Barstow
PACIFIC
Los Angeles
San Bernardino
San Onofre NPP
OCEAN
ARIZ
San Diego
El Centro
MEXICO

Figure 6. California air sampling program stations

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for January 1974.

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[1] Air samples near nuclear power reactors obtained under contract number AT(49-1)-3549 between the U.S. Atomic Energy Commission and the California Department of Health.

Table 5. Gross beta radioactivity in California air January 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	20	1.22	0.03	0.22
Barstow	29	1.08	.00	.21
Berkeley	30	.24	.00	.11
Diablo Canyon Nuclear Power Plant	8	.22	.02	.11
El Centro	22	.37	.01	.17
Eureka	19	.29	.00	.08
Fresno	12	.24	.03	.12
Humboldt Bay Power Plant: Unit 3	13	.11	.03	.07
Los Angeles	22	.45	.04	.15
Rancho Seco Nuclear Generating Station	13	.28	.00	.13
Redding	14	.31	.08	.19
Sacramento	21	.26	.03	.10
Salinas	22	.92	.01	.18
San Bernardino	20	1.03	.00	.22
San Diego	22	.59	.04	.17
San Luis Obispo	22	.45	.01	.15
San Onofre Nuclear Generating Station	4	.25	.06	.13
Santa Rosa	30	1.23	.00	.13
Summary	343	1.23	0.00	0.15

6. Plutonium in Airborne Particulates April–June 1973

Office of Radiation Programs
Environmental Protection Agency

The Radiation Alert Network (RAN) of the Division of Atmospheric Surveillance, Environmental Protection Agency, routinely collects airborne particulate samples from 11 selected RAN stations for plutonium analyses. The plutonium analyses were initiated in November 1965, and references to the previous results through December 1969 have been published (*1*).

One-half of each individual air filter from the selected stations is sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama. The laboratory analyzes a composite of these samples from each station on a quarterly basis. The results from April-June 1973 are presented in table 6. The minimum detectable activities are 0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively. The volume of air samples varies, generally ranging from 20,000 to 30,000 cubic meters per month.

Table 6. Plutonium in airborne particulates April-June 1973

Location		Plutonium-238 (aCi/m³)	Plutonium-239 (aCi/m³)	^{239}Pu/^{238}Pu
Alaska:	Anchorage	(a)	(a)	
Ariz:	Phoenix	4.5 ± 0.8	33.7 ± 3.7	7 ± 2
Colo:	Denver	2.9 ± .7	26.8 ± 3.2	9 ± 3
Hawaii:	Honolulu	1.0 ± .5	12.6 ± 2.0	13 ± 6
La:	New Orleans	2.6 ± .6	16.3 ± 2.1	6 ± 2
Md:	Baltimore	1.5 ± .5	16.8 ± 2.2	11 ± 4
N.Y:	Buffalo	2.4 ± .6	17.8 ± 2.3	7 ± 2
N.C:	Gastonia	2.6 ± .2	17.5 ± 2.3	7 ± 2
S. Dak:	Pierre	8.8 ± 4.5	24.3 ± 7.8	3 ± 2
Tex:	Austin	3.0 ± .7	22.1 ± 2.7	7 ± 2
Wash:	Seattle	1.4 ± .6	10.3 ± 2.0	7 ± 3

[a] Insufficient sample volume to obtain detectable levels of plutonium.

Other coverage in *Radiation Data and Reports:*

Period	Issue
April–June 1972	January 1973
July–September 1972	March 1973
October–December 1972	June 1973
January–March 1973	May 1974

REFERENCE

(*1*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–December 1969. Radiol Health Data Rep 11:552–553 (October 1970).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

A summary of the environmental radioactivity data follows for the Hanford Atomics Products Operation.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2]
January–December 1971

Battelle Pacific Northwest Laboratories
Richland, Wash.

The primary mission at the Hanford site of the Atomic Energy Commission (AEC) has been the production of plutonium. Activities have included nuclear fuel fabrication, plutonium production and test reactor operation, chemical separations of irradiated fuels, laboratory support and research, waste storage and disposal, and plant support operations. In recent years, privately-owned facilities, including a power generating station, office buildings, and a radioactive waste burial site, have been located within the Hanford site boundaries.

The Hanford site is in a semiarid region of southeastern Washington State (figure 1) where the average rainfall is about 16 cm (6 inches). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site generally have been put under irrigation during the past few years. The plant site covers an area of about 1300 km^2 (500 square miles). The Columbia River flows through the northern edge of the Hanford site and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The population center of primary interest is

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[2] Summarized from Pacific Northwest Laboratory, "Environmental Surveillance at Hanford for 1971," BNWL—1683 (August 1972).

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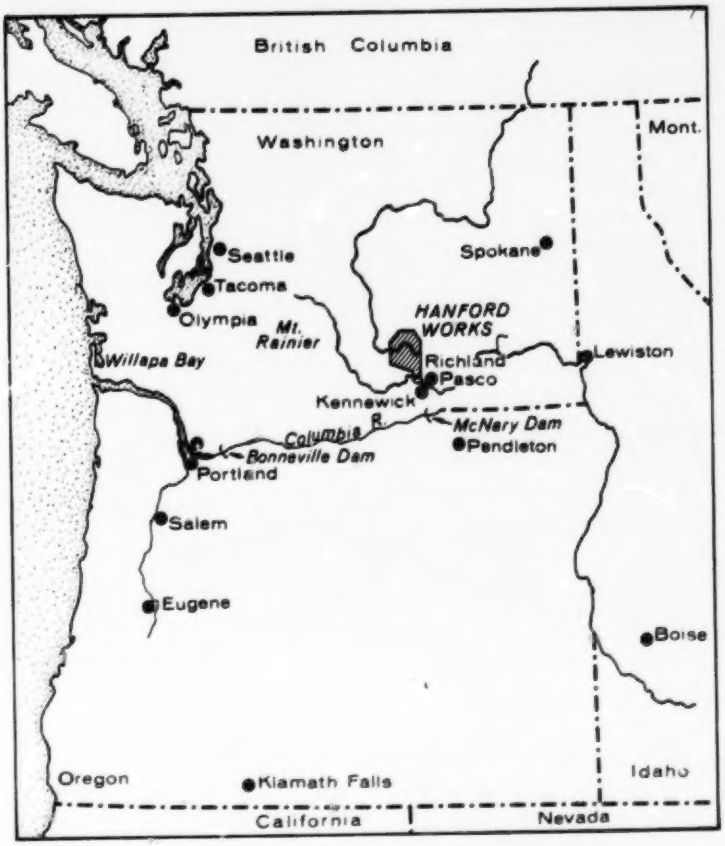
British Columbia
Washington
Mont.
Spokane
Seattle
Tacoma
Olympia
Mt. Rainier
HANFORD WORKS
Richland
Pasco
Kennewick
Lewiston
Willapa Bay
Columbia R.
McNary Dam
Pendleton
Bonneville Dam
Portland
Salem
Eugene
Boise
Oregon
Klamath Falls
Idaho
California
Nevada

Figure 2. Features of Hanford Project and vicinity

the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 100 000.

The farming area closest to the separations facilities is at Ringold, about 20 km (13 miles) away, but much of the land east and south of the project boundary is under cultivation and may be in the path of airborne releases. Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the operating reactors. The principal products from the larger farm plots are hay, fruit, beef, and dairy products.

Radioactive wastes continued to be generated during 1971 by the Hanford production reactors, chemical separations plants, and laboratories. High level wastes were concentrated and retained in storage in the chemical separations areas. Controlled releases of low-level wastes, for which concentration and storage were not feasible, were made to the ground, to the atmosphere, and to the Columbia River.

The most significant Hanford contributions to offsite radioactivity and population doses have in recent years usually originated with reactor once-through cooling water released to the Columbia River (*1*). At one time, nine production reactors, eight with once-through cooling, were in operation at Hanford. Beginning in December 1964, the older reactors with once-through cooling have been deactivated until only two production reactors remained in operation, N and KE. In January 1971, the last production reactor with once-through cooling by river water (KE) was shut down. As a result, the amount of radioactivity released to the Hanford environment, other than to soil within the plant reservation, decreased to relative insignificance. N reactor has a closed primary cooling loop and only releases minor quantities of radioactivity to the river.

Construction of a new reactor, the Fast Flux Test Facility and associated engineering facilities, was well underway in 1971. The reactor location is shown in figure 2. This reactor will use cooling towers for heat dissipation rather than the Columbia River.

The purpose of this annual report is to present a summary and evaluation of the combined offsite effects of effluents released to uncontrolled areas by all Hanford contractors during 1971 in compliance with AECM-0513 (*2*).

Radioactivity in the Columbia River

N reactor, the only production reactor remaining in operation at Hanford after January 1971, uses recirculating, demineralized water as a primary coolant. Waste water containing some radioactive material is discharged

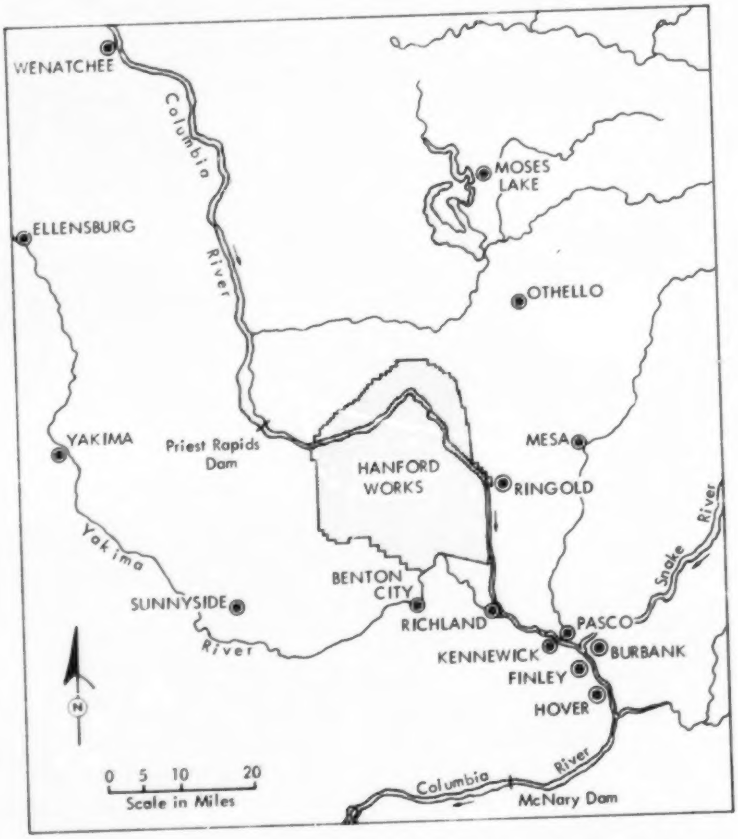
WENATCHEE
Columbia River
MOSES LAKE
ELLENSBURG
OTHELLO
YAKIMA
Priest Rapids Dam
HANFORD WORKS
MESA
RINGOLD
Snake River
Yakima River
BENTON CITY
SUNNYSIDE
RICHLAND
PASCO
KENNEWICK
BURBANK
FINLEY
HOVER
N
0 5 10 20
Scale in Miles
Columbia River
McNary Dam

Figure 1. Geographical relationship of Hanford to the Pacific Northwest

to the ground. Many of the radionuclides are shortlived and disappear quickly due to radioactive decay before reaching the river; others are largely absorbed on soil particles and retained in the soil. The small quantities of nuclides reaching the river from N reactor usually have been diluted well below detection level in the river.

Seasonal fluctuations in the flow-rate of the Columbia River affect radionuclide concentrations by varying the quantity of water available for dilution of reactor effluent released to the river. In addition, scouring by high river flows of sediments deposited in reservoirs behind each dam causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments. This has been notably true for scandium-46 and zinc-65. Also affected by the river flow rate is the time required for a specific volume of water to move downstream, which in turn affects the extent of decay of shorter-lived nuclides.

Figure 3 shows the weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams determined from daily average flow rates published by the U.S. Geological Survey (USGS) (*3*). For 1971, the average river flow rate at Priest Rapids was 3820 m^3/s (135 000 cubic feet/s) which was slightly above the 1948–1962 annual average of 3770 m^3/s (133 000 cubic feet/s).

During 1971, samples of Columbia River water were collected at Vernita Toll Bridge near the upstream Hanford boundary and at the Richland water plant intake, near the downstream boundary, as well as McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. Concentrations of radionuclides with relatively short half-lives were measured in monthly "grab" samples.

Sampling traverses across the Columbia River at Richland have indicated a slightly nonuniform distribution of the longer-lived radionuclides at this cross section. Entries of the Yakima River just below Richland and of the Snake River just below Pasco influence the distribution of radionuclides in the Columbia below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries.

Table 1 shows the maximum, minimum, and annual average radionuclide concentration in Columbia River water at Vernita and Richland for 1971. Possible Hanford contribution to the

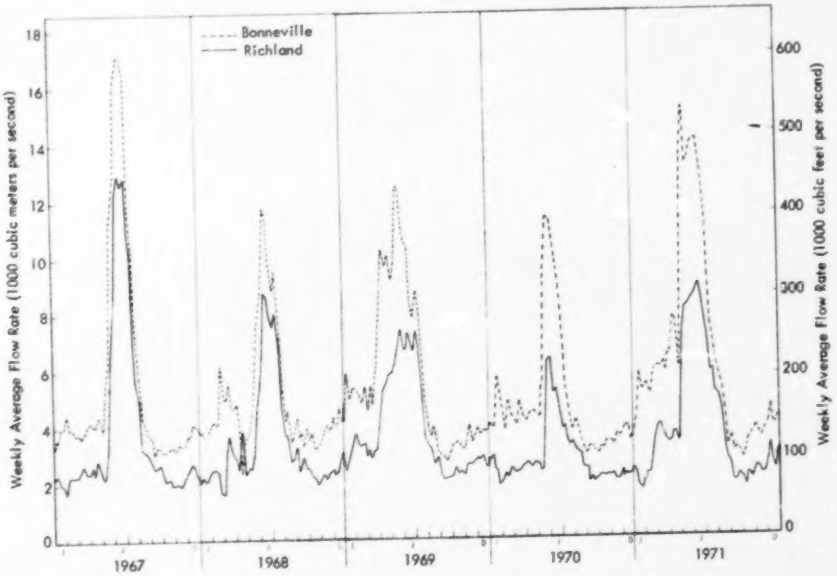

Figure 3. Columbia river flow rates

Table 1. Average concentration of radionuclides in Columbia River water for 1971

Radionuclide	Concentration (pCi/liter)											
	Analytical limit	Number of samples	Vernita			Percent of AEC standard	Number of samples	Richland			Percent of AEC standard	Concentration guide
			Maximum	Minimum	Average			Maximum	Minimum	Average		
Alpha	0.3	12	1.2	0.46	0.84	2.8	12	1.8	0.54	1.01	3.4	30
Tritium	600.0	12	4300	[a]0	1100	.04	12	1500	[a].0	780	.03	3×10⁶
Phosphorus-32	6.0	NS	------	------	------	------	5	50.0	[a].0	2.5	.003	20 000
Scandium-46	8.0	NS	------	------	------	------	21	50.0	[a].0	5.2	.01	40 000
Chromium-51	40.0	NS	------	------	------	------	51	590	[a].0	85.0	.004	2×10⁶
Zinc-65	10	NS	------	------	------	------	21	35.0	[a].0	4.5	.005	100 000
Strontium-90	.06	12	.54	.16	.36	.12	12	3.8	[a].32	.85	.28	300
Iodine-131	2.0	NS	------	------	------	------	47	4.0	[a].0	.41	.01	300
Cesium-137	3.0	3	[a]1.2		[b].41	.002	50	28.0	[a].0	5.9	.03	20 000
Uranium (natural)	3.4	NS	------	------	------	------	5	4.1	3.4	3.4	.02	20 000

[a] Less than analytical limit.
NS, no sample.
[b] Best estimate.

average river radionuclide concentrations is less than 1 percent of the AEC standards for water for all the radioisotopes in table 1, except for alpha which is 3.4 percent of the AEC radiation standard for an unknown mixture of alpha-emitters. Past analyses have shown the natural uranium in the river water to account for at least 90 percent of the total alpha. Figures 4 and 5 show the river transport rates of five radionuclides past Richland. The transport rates at Richland in 1971 for the five radionuclides show the disappearance of the shorter-lived radionuclides following the KE reactor shutdown. Some intermittent transport of previously deposited nuclide-bearing sediments continued to give occasional positive transport values.

Bonneville Dam, approximately 490 km (240 miles) below the N reactor, is the farthest downstream location where river water is

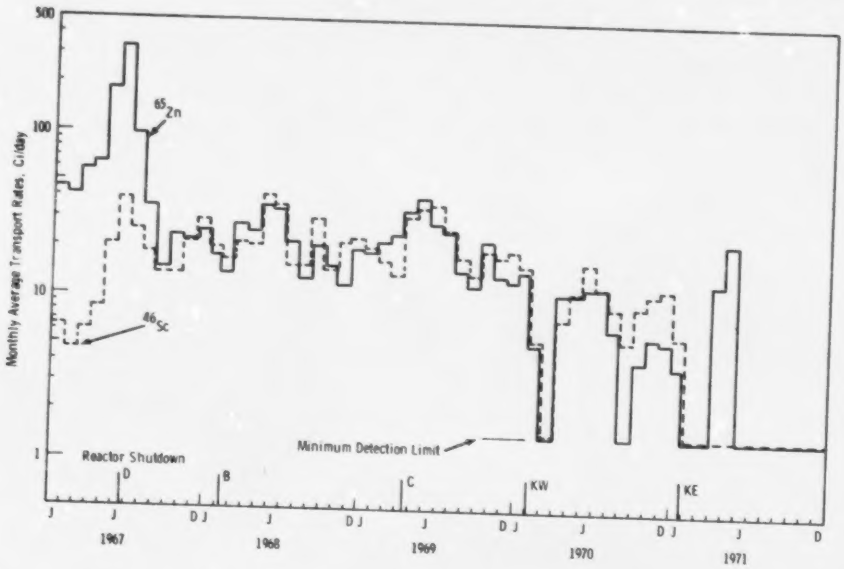

Figure 4. Scandium-46 and zinc-65 transport rates in the Columbia river at Richland (Ci/day)

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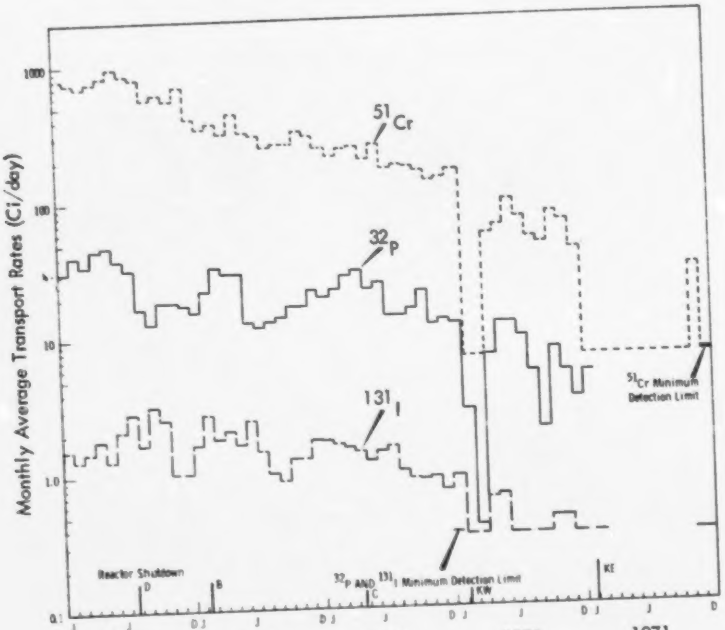

Figure 5. Transport rates in the Columbia river at Richland

sampled routinely as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 2).

Table 2. Annual average transport rate of selected radionuclides past Bonneville Dam, 1967–1971

Radionuclide	Transport rate (Ci/day)				
	1967	1968	1969	1970	1971
Phosphorus-32	12	6.2	7.1	<2.3	NA
Scandium-46	10	7.5	NA	NA	<1.5
Chromium-51	610	200	100	<40	NA
Zinc-65	40	<13	<15	<4.7	<3.7

NA, no analysis.

Radioactivity in drinking water

The City of Richland, about 75 km (45 miles) downstream from N reactor is the first community below the project that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few miles further downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; water for Kennewick is pumped from Raney well collectors (infiltration pipes) laid in the riverbed. During 1971, cumulative and grab drinking water samples were collected at the Richland water plant and were analyzed for selected individual radionuclides and gross beta activity (table 3).

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 3 because there can be a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand. Average radionuclide concentrations in Richland drinking water samples were much less than 1 percent of the AEC standards for water except for alpha, which was about 4 percent of the standard for an unknown mixture of alpha

Table 3. Average concentrations of several radionuclides in Richland drinking water, 1971

Radionuclide	Concentration (pCi/liter)					
	Analytical limit (pCi/liter)	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Alpha	0.3	9	2.15	[a] 0.16	[b] 1.2	4
Beta[c]	.02	45	.056	[a] .0	<.016	—
Phosphorus-32	6.0	6	27.2	[a] 3.1	[d] 9.5	.05
Scandium-46	8.0	46	38.3	[a] .0	4.1	.01
Chromium-51	40.0	46	716	[a] .0	110	.006
Cobalt-60[e]	2.0	46	24.1	.0	1.8	.006
Zinc-65	10.0	52	186	[a] .0	12.0	.01
Strontium-90	.06	2	.401	.35	[b] .380	.01
Iodine-131	2.0	6	2.03	[a] .51	[d] <.89	.30

[a] Less than analytical limit.
[b] November and December only.
[c] Counts per minute per milliliter.
[d] January and 1st week of February only.
[e] AEC standard-50 000 pCi/liter.

emitters. As stated earlier, most of the alpha activity in the Columbia River, and therefore Richland drinking water, does not result from Hanford operations.

Groundwater data

An extensive groundwater monitoring program continued to show little, if any, measurable effect on Columbia River quality from low-level wastes released to ground disposal sites within the Hanford plant boundaries. The data from this program continued to be documented separately, the most recent report in this series being BNWL-1649 (4). A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to these confined aquifers, are sampled routinely for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from recent precipitation also can occur. Table 4 shows data from these wells for 1971. The high value for the White Bluffs Association well resulted from one positive sample of 5300 pCi/liter (less than 0.2 percent of the applicable AEC radiation standards), which is not believed to be of Hanford origin since other data from this well and the data from other deep wells closer to plant facilities continued to give negative results.

Table 4. Groundwater tritium analysis from wells in the vicinity of Hanford Plant, 1971

Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard
		Maximum	Minimum	Average	
Webber	2	<940	<520	<730	<.02
Vail	2	<780	<520	<650	<.02
W-15	2	<730	<680	<700	<.02
White Bluffs Association	3	5 300	<510	<2 200	<.07

Radioactivity in the atmosphere

Gaseous effluents from the Hanford chemical separations facilities are released to the atmosphere through tall stacks after passage through high efficiency filters. Laboratory stacks, reactor-building stacks, and stacks from waste storage facilities also may release small amounts of radioactive materials after high efficiency filtration.

During 1971, measurements of airborne iodine-131, total beta, and total alpha were made (as of the end of 1971) at 23 locations around the Hanford reservation. Figure 6 shows the locations of offsite air sampling stations. Figures 7 and 8 show the monthly average iodine-131 and particulate beta radioactivity in the atmosphere from both nearby locations in the direction of the prevailing wind (eastern quadrant) and from more distant perimeter communities.

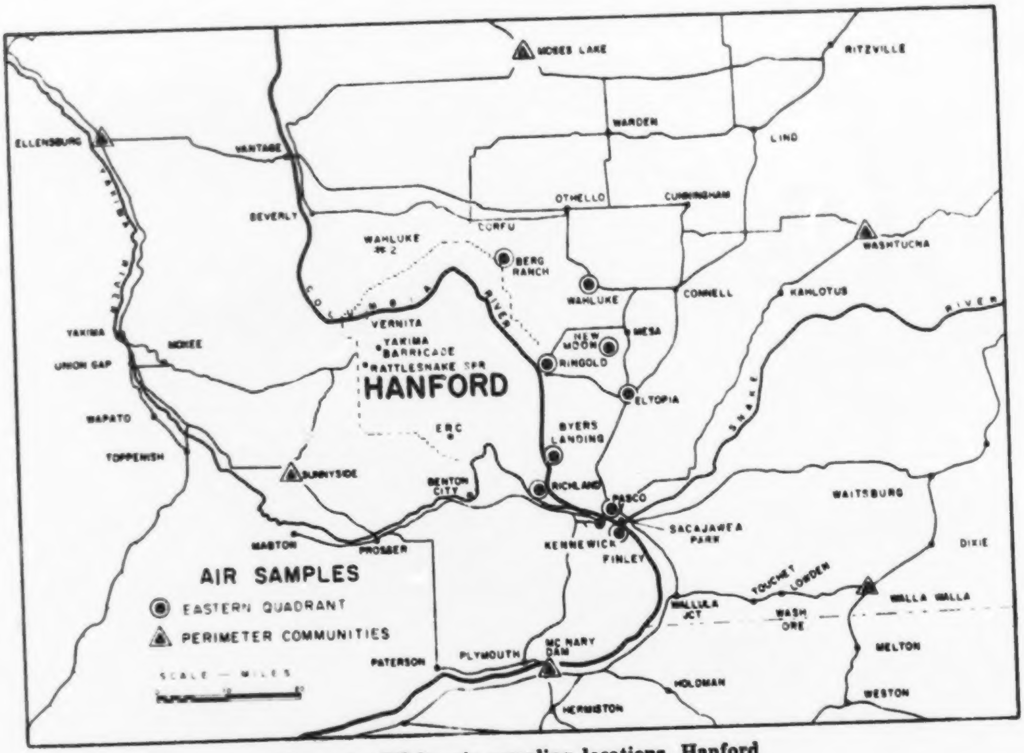
MOSES LAKE
RITZVILLE
WARDEN
LIND
ELLENSBURG
VANTAGE
OTHELLO
CUNNINGHAM
BEVERLY
CORFU
WAHLUKE
WASHTUCNA
BERG RANCH
WAHLUKE
CONNELL
KAHLOTUS
RIVER
YAKIMA
MOXEE
VERNITA
YAKIMA BARRICADE
NEW MOON
MESA
UNION GAP
RATTLESNAKE SPR
RINGOLD
HANFORD
ELTOPIA
WAPATO
ERC
BYERS LANDING
SNAKE
TOPPENISH
SUNNYSIDE
BENTON CITY
RICHLAND
PASCO
WAITSBURG
SACAJAWEA PARK
KENNEWICK
MABTON
PROSSER
FINLEY
DIXIE
AIR SAMPLES
EASTERN QUADRANT
PERIMETER COMMUNITIES
TOUCHET
LOWDEN
WALLULA JCT
WALLA WALLA
WASH ORE
PATERSON
PLYMOUTH
MC NARY DAM
MELTON
SCALE — MILES
HOLDMAN
HERMISTON
WESTON

Figure 6. Offsite air sampling locations, Hanford

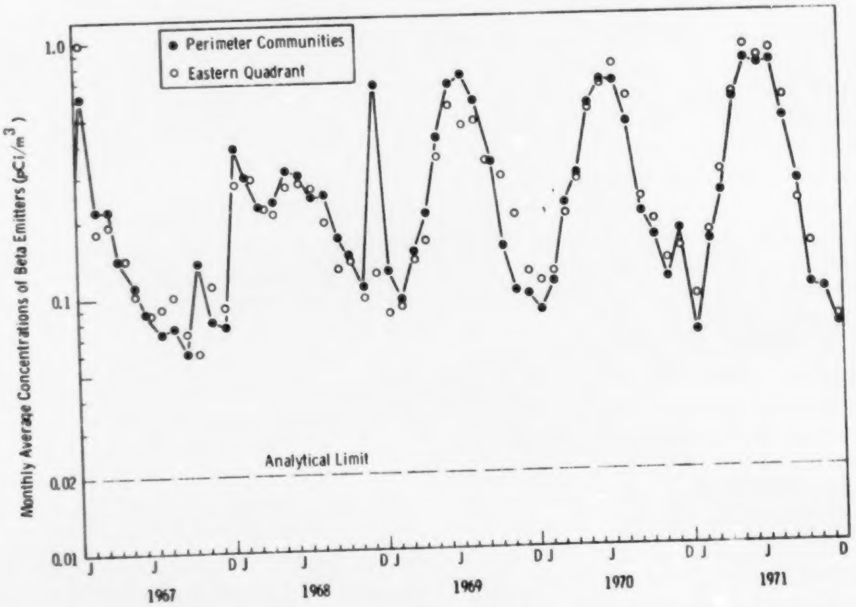

Figure 7. Monthly average particulate total beta concentration in the air of Hanford environs

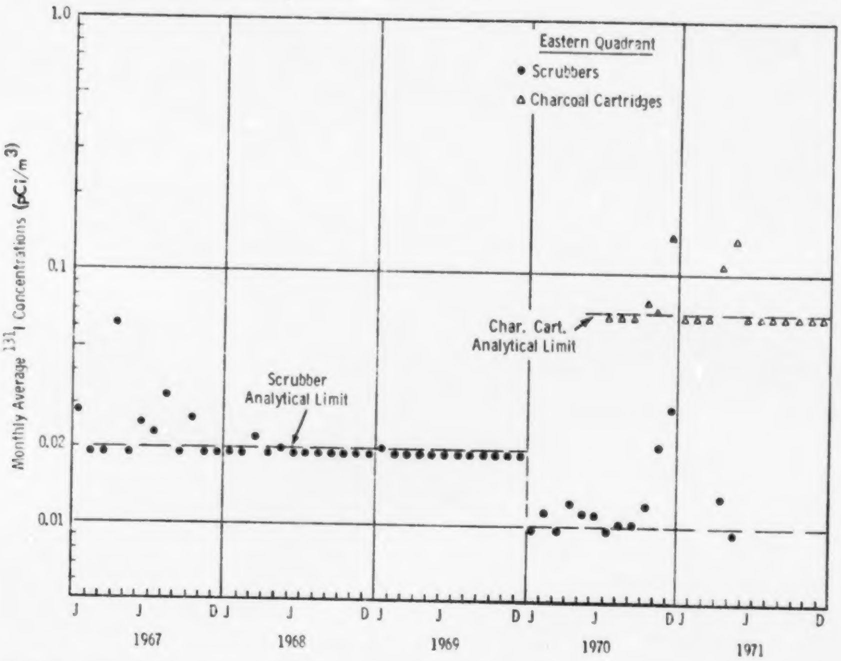

Figure 8. Monthly average iodine-131 concentrations in the air of Hanford environs

In mid-1970, caustic scrubbers for radioiodine sampling were replaced with activated charcoal cartridges. The activated charcoal has a much greater collection efficiency than the caustic solution for organic-bound radioiodines. Therefore, the apparently increased radioiodine concentrations noted after June 1970 only reflect this increased collection efficiency and not an actual change in airborne radionuclide concentrations. Airborne beta concentrations followed the annual cycle observed in previous years and showed about the same maximum and minimum values. Table 5 presents a more detailed review of the 1971 airborne radioactivity data and includes data from the sampling locations on or near the plant boundary. Activated charcoal sampling for iodine-131 was performed at the perimeter community locations but the samples were occasionally analyzed only when radioiodine was detected in other samples. Special analyses generally showed strontium-90 to account for less than 10 percent of the total beta radioactivity, which would raise the actual AEC radiation standard to 100 pCi/m^3. Average beta concentrations were less than 5 percent of the more restrictive AEC standards. Airborne alpha concentrations averaged less than 15 percent of the AEC standards for air and average iodine-131 concentrations were less than 0.1 percent of the AEC standards for air. Generally, the average airborne radioactivity concentrations at the Hanford boundary were the same as the more distant sampling locations, indicating that Hanford operations were not contributing significantly to offsite airborne radioactivity.

Radionuclides in milk

Irrigation with river water containing radionuclides can contribute radioactivity to local milk and locally grown farm produce, as can deposition of airborne materials from Hanford sources and from weapons test fallout. Chemical separations facilities would generally be the principal local source of airborne radionuclides other than fallout, although unusual radio-

Table 5 Radioactivity in air for 1971, Hanford Plant

Location	Alpha emitters (pCi/m³)					Beta emitters (pCi/m³)					Iodine-131 (pCi/m³)				
	Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard	Number of samples	Maximum	Minimum	Average	Percent of AEC standard
Plant boundary sampling points:															
Yakima Barricade	25	0.012	[a]0.001	0.003	15	25	1.4	0.07	0.42	4.2	26	0.16	[a]0.006	0.004	0.004
Vernita	NS	----	----	----	----	26	2.1	.07	.47	4.7	NS	----	----	----	----
Wahluke #2	NS	----	----	----	----	27	1.2	.06	.42	4.2	NS	----	----	----	----
Berg Ranch	27	.015	[a].001	.002	10	27	1.3	.06	.44	4.4	27	.19	[a].015	.019	.019
Ringold	26	.015	[a].001	.003	15	26	1.3	.04	.39	3.9	27	.24	[a].0005	.023	.023
Byers Landing	25	.010	[a].001	.003	15	25	1.1	.06	.39	3.9	26	.15	[a].0003	.031	.031
Richland	26	.010	[a].001	.001	5	26	1.2	.06	.42	4.2	27	.34	[a].007	.037	.037
ECC	NS	----	----	----	----	25	1.0	.07	.40	4.0	NS	----	----	----	----
Rattlesnake Spring	NS	----	----	----	----	25	1.4	.08	.46	4.6	NS	----	----	----	----
' enton City	26	.014	[a].001	.001	5	26	1.4	.07	.42	4.2	27	.11	[a].004	.021	.021
Intermediate sampling points:															
Othello	24	.003	[a].001	.001	5	27	1.0	.05	.38	3.8	27	.19	[a].003	.032	.032
Wahluke Watermaster	NS	----	----	----	----	24	1.0	.03	.38	3.8	26	.20	[a].001	.012	.012
Connell	NS	----	----	----	----	27	1.3	.03	.44	4.4	27	.68	[a].004	.065	.065
New Moon	18	.002	[a].001	.001	5	26	.89	.03	.30	3.0	27	.18	[a].003	.023	.023
Eltopia	NS	----	----	----	----	27	1.1	.04	.39	3.9	NS	----	----	----	----
Pasco	26	.016	[a].001	.003	15	26	1.2	.05	.42	4.2	26	.28	[a].002	.031	.031
Kennewick	NS	----	----	----	----	25	.90	.06	.38	3.8	NS	----	----	----	----
Distant sampling points:															
Sunnyside	NS	----	----	----	----	26	1.0	.05	.34	3.4	NS	----	----	----	----
Ellensburg	NS	----	----	----	----	23	1.1	.04	.31	3.1	NS	----	----	----	----
Moses Lake	NS	----	----	----	----	25	1.3	.06	.40	4.0	NS	----	----	----	----
Washtucna	NS	----	----	----	----	24	1.1	.04	.37	3.7	NS	----	----	----	----
Walla Walla	21	.003	[a].001	.001	5	26	1.0	.05	.35	3.5	NS	----	----	----	----
McNary Dam	18	.002	[a].001	.002	10	25	1.0	.07	.41	4.1	NS	----	----	----	----
Analytical limit			0.001					0.02					0.07		
AEC standard			0.02					10					100		

[a] Less than analytical limit.
NS, no sample.

activity releases from ventilation stacks of reactor or laboratory facilities could be of interest.

The milk surveillance program maintained during 1971 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained zinc-65 and iodine-131, as well as fission products of fallout origin. Prior to February 1971 (no single-pass reactors operated after January 1971), milk from these farms contained detectable phosphorus-32. However, commercial milk distributed in the tri-cities usually did not contain detectable phosphorus-32 and zinc-65 because only a small fraction of this milk was produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

Figure 9 shows the monthly average concentration of phosphorus-32 and zinc-65 in milk from river-irrigated farms in the Ringold and Riverview area for 1967–1971. Phosphorus-32 analysis was discontinued after February 1971. Seasonal fluctuations in radionuclide concentrations, caused primarily by irrigation and feeding practices, followed expected trends. Average phosphorus-32 and zinc-65 concentrations in milk for 1971, as shown in table 6, were less than 0.1 percent of the AEC radiation standards. Even so, such concentrations would have been available only to a few local families.

Figure 10 shows the monthly average concentrations of iodine-131 in locally available milk. During 1971, iodine-131 concentrations in both farm milk and commercial milk generally were near or below the analytical limit

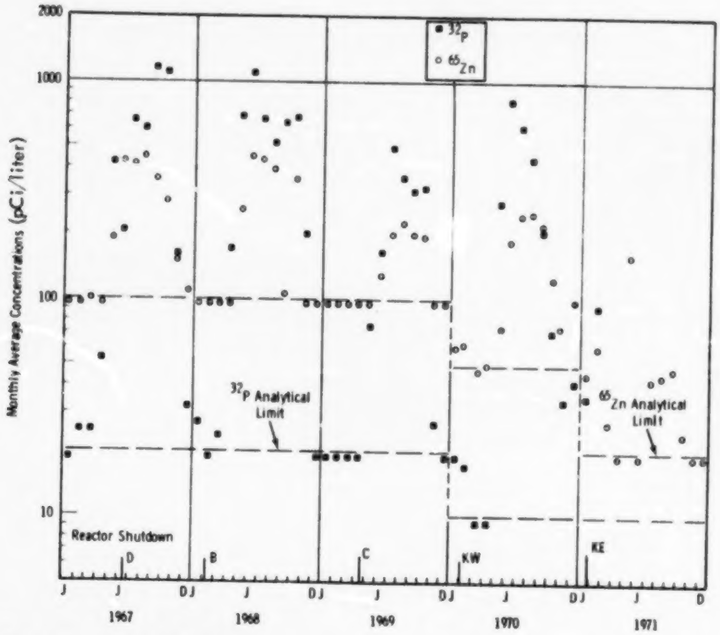

Figure 9. Monthly average phosphorus-32 and zinc-65 concentrations in milk from river-irrigated farms, Hanford

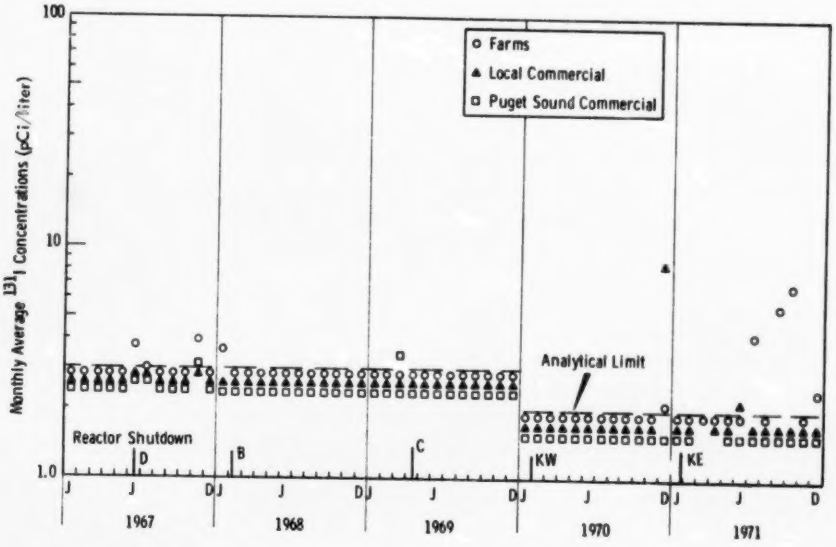

Figure 10. Monthly average iodine-131 concentrations in locally available milk, Hanford

Table 6. Radionuclide concentrations in locally purchased milk, 1971

Sampling location	Number of samples	Radionuclide concentration (pCi/liter)									
		Phosphorus-32		Zinc-65		Strontium-90		Iodine-131		Cesium-137	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Riverview	1	100	[a] 15	220	54	5	2	2	[a] 1	28	[a] 18
Benton City and West Richland composite	52	([a])	([a])	210	22	3	2	25	[a] 1	92	[a] 16
Columbia River basin composite	52	([a])	([a])	200	25	2	[a] 1	3	[a] 1	81	[a] 18
Commercial	2	([a])	([a])	170	28	6	4	3	[a] 1	50	26
AEC standard		20 000		100 000		300		300		20 000	
Analytical limit (water)		20		20		2		2		20	

[a] Less than analytical limit.
Note: Minimum detected activities were all below the analytical limit and therefore not included in this table.

(2 pCi/liter). The maximum iodine-131 concentration for this period, (25 pCi/liter) was measured in a single sample of farm milk collected on December 2. The average iodine-131 concentrations locally available in farm milk for 1971 (table 6) were less than 0.5 percent of the AEC standards for water. Increases of iodine-131 concentrations in milk, attributed to fallout from atmospheric nuclear weapons testing, were observed the latter part of 1971.

The concentrations of other fallout nuclides, strontium-90 and cesium-137, in the local environs usually are below the national average because of the low rainfall. Measurements of fallout, like measurements of natural background radiation, help to put the radionuclide concentrations resulting from Hanford operations, in proper perspective.

Concentration of strontium-90 in locally produced farm and commercial milk (figure 11) are similar to those in commercial milk produced in other areas of low rainfall remote from the Hanford plant. Concentrations of cesium-137 (figure 12) averaged near the analytical limit of 20 pCi/liter. Regional fallout from nuclear weapons testing is the source of strontium-90 and cesium-137 in milk.

Concentrations of strontium-90 and cesium-137 in locally available milk averaged less than 1.4 percent and 0.5 percent of the respective AEC Radiation Protection Standards (*5*) for water.

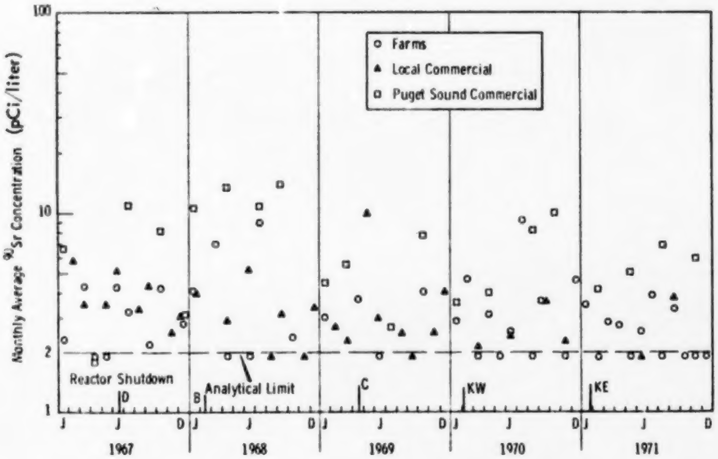

Figure 11. Monthly average strontium-90 concentrations in locally available milk, Hanford

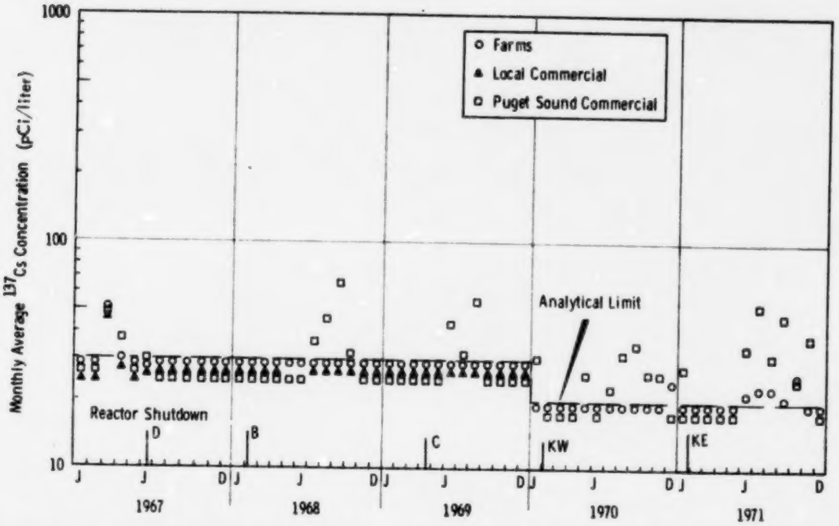

Figure 12. Monthly average cesium-137 concentrations in locally available milk, Hanford

Radionuclides in foods

A program of sampling the meat and produce of local farms and stores was conducted throughout 1971. Sampling schedules were geared to local foodstuff production schedules. Meat was obtained from Riverview farms and local stores. Leafy vegetables were obtained from Riverview farms in July, August, and September, and from local stores in May through October. Table 7 shows that, on the average, concentrations of reactor-produced zinc-65 were higher in local farm foodstuffs than in locally available commercial products.

Table 7. Radionuclide concentrations in locally purchased food, 1971

Foodstuffs	Number of samples	Radionuclide concentration (pCi/g wet weight)							
		Phosphorus-32		Zinc-65		Strontium-90		Zirconium-niobium-95	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
Commercial meat	12	(a)	(a)	(a)	(a)	0.013	0.003	(a)	(a)
Poultry	2	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Eggs	10	(a)	(a)	0.93	0.23	.012	.007	(a)	(a)
Local produce	3	(a)	(a)	[a] .023	[a] .014	(a)	(a)	0.13	0.021
Commercial produce	5	(a)	(a)	(a)	(a)	.039	.008	.046	.046
Analytical limit			1.0		0.030		0.002		0.010

Foodstuffs	Number of samples	Ruthenium-106		Iodine-131		Cesium-137		Cerium-praseodymium-144	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	ver-age
Commercial meat	12	(a)	(a)	(a)	(a)	0.194	0.053	(a)	(a)
Poultry	2	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Eggs	10	(a)	(a)	(a)	(a)	(a).015	(a)	(a)	(a)
Local produce	3	(a)	(a)	(a)	(a)	.046	(a).016	(a)	(a)
Commercial produce	5	3.3	0.82	(a)	(a)	.18	.047	5.3	1.5
Analytical limit			0.370		0.025		0.017		0.350

[a] Less than analytical limit.
Note: Minimum detected activities were all below the analytical limit and therefore not included in this table.

Conversely, the concentrations of fallout radionuclides (strontium-90, cesium-137, cerium praseodymium-144, zirconium-niobium-95, and ruthenium-106) were higher in the commercial foodstuffs. Although concentration or daily intake guides for radionuclides other than strontium-90 and cesium-137 are not specifically available for foods, it is common practice and provides an appropriate perspective to compare radionuclide concentrations in foods with AEC standards for water, keeping in mind that such a comparison implies continued daily intake of foodstuffs. Radionuclides in milk and food are shown in tables 6 and 7.

Radionuclides in fish, shellfish, and gamebirds

Fish in the Columbia River downstream from the single-pass Hanford reactors acquired radionuclides originating with reactor effluent. Historically, whitefish were the fish species caught and consumed locally that usually contained the greatest concentrations of radioactive material. However, panfish species were of greater significance as a source of human exposure due to the difference in quantities consumed (*6*). Phosphorus-32 concentrations in whitefish dropped to less than the analytical limit of 1 pCi/g wet weight within a month after shutdown of the KE reactor. Radionuclide concentrations of other nuclides and other fish species would have been of even less significance as a source of human exposure. Zinc-65 and phosphorus-32 are the only radionuclides from Hanford reactor effluents that have been found in sufficient abundance in food organisms beyond the mouth of the Columbia River to be of significance to human radiation exposure. Oysters have been found to contain higher concentrations of zinc-65 than other common seafoods (*7*). A normal seasonal minimum for phosphorus-32 occurs in the late summer, due to seasonal changes of ocean currents. For 1971, the concentrations of phosphorus-32 were so low that negligible quantities of phosphorus-32 were found in Willapa Bay oysters. Concentrations of zinc-65 decreased at a rate closely corresponding to its radioactive decay.

Waterfowl and other gamebirds utilizing the river downstream from the reactors may acquire radionuclides as a result of ingestion of insects, algae, vegetation, and water containing these radionuclides. Some water fowl remain in this general area throughout the year. The concentrations of radionuclides in game birds are dependent upon the bird species, the geographical locations of the birds, and their current feeding habits. Data from a dietary survey of Hanford employees and from a special survey of local hunters (*8*) indicate that about 30 percent of the game bird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. The same studies showed that about 30 percent of all gamebirds taken locally were ducks and geese, and that the average Richland resident consumed 1.4 kg/yr of gamebirds.

Table 8. Average radionuclide concentrations in muscle of gamebirds, 1971

Species	Radionuclide concentration (pCi/g)															
	Sodium-24				Phosphorus-32				Zinc-65				Cesium-137			
	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average
Geese (river)[a]	10	[b]	[b]	[b]	10	1.2	[b] 0	[b] 0	10	1.4	[b]	0.57	10	0.55	[b] 0	0.097
Duck (river)[a]	79	5.2	[b]	0.97	31	170.0	[b] 0	19	79	15.0	[b] 0	.63	79	.28	[b] 0	.046
Pheasant [c]	NA	NA	NA	NA	NA	NA	NA	NA	16	.35	[b] 0	[b]	16	.13	[b] .002	.08
Analytical limit	0.6				1.0				0.2				0.1			

[a] Collected in January 1971 on the Columbia River within the Hanford boundary.
[b] Less than analytical detection limit.
[c] Collected in November and December 1971 within 5 km (3 miles) of the Columbia River and within the Hanford boundary.
NA, no analysis.

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The average concentrations of several radionuclides in the muscle (the edible portion) of 89 waterfowl samples collected on the river within the Hanford boundaries for the environmental monitoring program during hunting seasons in 1971 are shown in table 8. Average radionuclide concentrations in muscle for 16 pheasants collected at the Hanford site also appear in table 8.

Radionuclide concentrations in gamebirds in 1971 generally were below the levels recorded in 1970. Geese generally were lower in radionuclide concentrations than ducks taken from the same areas. Only zinc-65 was consistently above detectable limits after the KE reactor shut down.

There are no appropriate AEC standards with which to compare the gamebird radionuclide concentrations because of the limited period of the year during which hunting is permitted and consumption usually occurs.

Dose estimates using the dietary studies (*6,8,9*), combined with concentration data from the various species, indicated that the dose received by the average Richland resident (adult) from gamebird consumption was less than 1 mrem for 1971.

Soil and vegetation

Thirteen stations for routine soil and vegetation sampling were established around the perimeter of the Hanford reservation in 1971. Samples of the top 5 cm (2 inches) of soil and native vegetation (perennial) were taken at each of these stations at the end of September, and analyzed for plutonium, strontium-90, and gamma emitters. The averaged results from all stations are given in table 9. Individuals results, tabulated in BNWL-1683 (ADD) showed no particular geographical pattern, and the concentrations measured are believed to be the result of regional fallout.

Gamma emitters in soil samples were measured with a germanium crystal detector; in vegetation samples, with a sodium iodide crystal. As a result, slight differences in the gamma spectra were reported. Since the bulk of the vegetation was perennial, no conclusions should be drawn as to uptake of radionuclides from the soil. The plutonium concentrations are typical of general regional levels for the arid western states. No valid standards exist for nuclides in soil and desert vegetation.

External radiation

Clusters of three ionization chambers[3] are maintained at selected locations within the plant boundary and at Richland and have been used to measure the gamma radiation exposure at 1 meter above ground level for many years (table 10), although it was recognized that the results were conservatively high. Thermo-

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[3] Victoreen stray radiation chambers, 100-ml.

Table 9. Radionuclides in soil and vegetation, 1971

Radionuclides	Concentration (pCi/g wet weight)					
	Soil			Vegetation		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Cobalt-58	0.08	(*)	0.017	(*)	(*)	(*)
Cobalt-60	.12	(*)	.032	(*)	(*)	(*)
Zinc-65	.29	(*)	.068	(*)	(*)	(*)
Strontium-90	.99	(*)	.18	0.78	0.07	0.21
Zirconium-niobium-95	(*)	(*)	(*)	2.7	.68	1.6
Ruthenium-106	2.3	(*)	.45	2.71	(*)	.95
Cesium-137	1.3	.33	.66	.82	.15	.43
Cerium-praseodymium-144	1.2	(*)	.44	10.6	1.1	4.7
Plutonium-238	.0067	(*)	.0029	.0038	(*)	(*)
Plutonium-239, 240	.018	(*)	.011	.011	(*)	.004

* Less than analytical limit.

Table 10. Radiation exposure rates at Richland from ionization chambers, 1967–1971

Location	Exposure rate (mR/yr)				
	1967	1968	1969	1970	1971
Hanford test location	0.35	0.36	0.37	0.39	0.40
Richland	.26	.28	.30	.34	.34

luminescent dosimeters (TLD-200)[4] were introduced into the routine surveillance program in 1970, and were available for the full year of 1971. Although table 11 is included as an indication of long-range trends, the more significant data for 1971 is a comparison of annual average exposure data from all monitored locations (the same as air sampling locations, figure 6). This shows the same value of 58 mR/yr for both eastern quadrant locations, adjacent to the Hanford plant, and the more remote perimeter communities locations.

Estimates of the external radiation dose received from recreational use of the Columbia River in the vicinity of the Hanford project have been based on routine measurements at the shoreline at Richland and Sacajawea Park (where the Snake River enters the Columbia) and below the surface of the river at Richland. The average exposure rates at the two shoreline locations (figure 13) were taken from measurements with a large (40 liter) ionization chamber prior to July 1971, and with a low-level dose rate meter[5] subsequently. Measurements were taken at 1 meter back from the water's edge and centered 1 meter above the ground, which approximates the dose rates to the gonads of a person on the riverbank. The exposure rates measured at the shoreline include components from radioactivity accumulated in sediment deposits and algae growths at the river's edge as well as from any radioactive material in the water. The same data, tabulated

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[4] Harshaw Chemical Company, $CaF_2(Dy)$.
[5] Nuclear Enterprises Model.

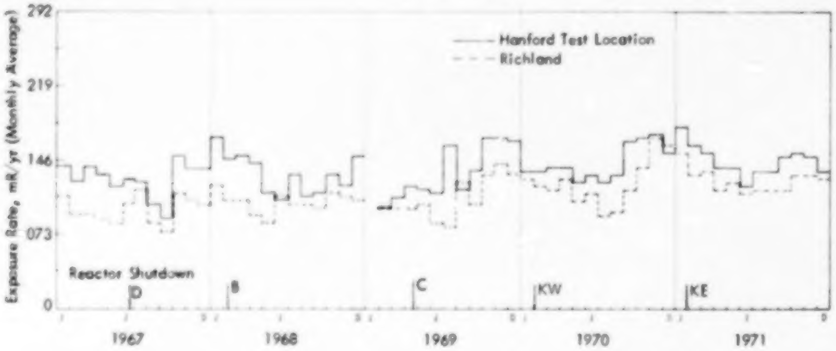

Figure 13. Monthly average gamma rates at Hanford test location and at Richland

Table 11. Radiation exposure rates at the Columbia River shoreline, 1967–1971

Location	Exposure rate															
	1968				1969				1970				1971			
	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)	(mR/day)			(mR/yr)
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
Richland	3.6	.12	1.1	400	1.5	0.30	0.71	260	1.1	0.14	0.44	160	0.77	0.12	0.30	110
Sacajawea Park	1.5	.24	.67	240	1.5	.30	.60	220	1.3	.24	.52	190	.60	.12	.30	110

in table 11, show the effect of shutdown of the single-pass reactors. Averages for 1971 are not significantly different from local background measurements with the same instrument.

The immersion dose received by tri-city swimmers is based on April through October exposure rates at Richland measured with thermoluminescent dosimeters positioned about 1 meter below the surface of the Columbia River. Measured immersion exposure rates primarily were due to the gamma emitters in the river. In the vicinity of Richland, the average measured immersion exposure rate from April through October 1971 was 0.15 mR/day, attributed to natural radioactivity.

Table 12. Comparable dose estimates* for average Richland resident, 1967–1971

Organ	Percent of AEC standard					Dose standard (mrem/yr)
	1967	1968	1969	1970	1971	
Bone	3	3	3	2	<1	500
Whole body	3	2	2	1	<1	170
GI tract	6	5	4	2	<1	500
Thyroid (infant)	8	8	5	2	<1	500

* Not including contributions from fallout of natural background radiation.

Population dose implications

Since 1958, a major part of the environmental surveillance effort at Hanford has been addressed to the estimation of radiation doses

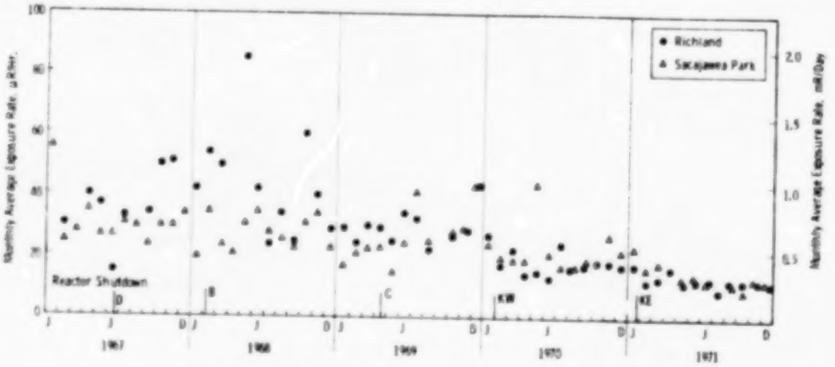

Figure 14. Monthly average external gamma exposure rates at the Columbia river shoreline at Richland and Sacajawea Park

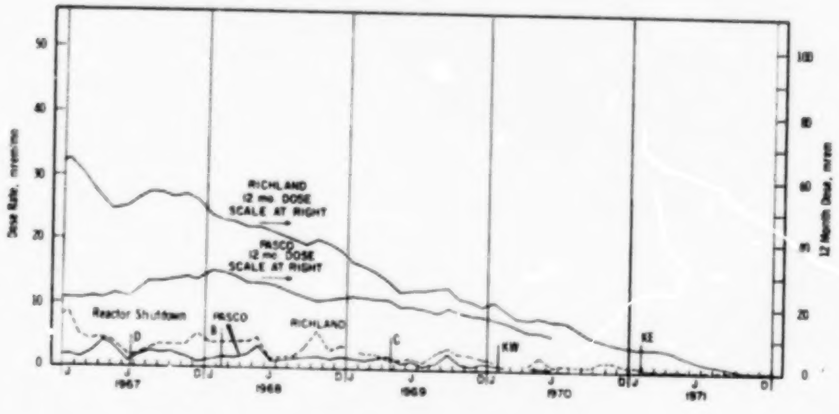

Figure 15. Doses to the G.I. tract from Richland and Pasco drinking water (1.86 liter/day intake rate)

Table 13. Radiation dose commitments from ingestion of fallout nuclides and comparison with radiation doses from plant sources, 1971

Organ	Dose (mrem)				
	Tritium	Strontium-90	Cesium-137	Total from fallout	Total dose from plant sources
Maximum individual:					
Bone		[b] 30	1	31	3
Whole body	<1	[b] 3	[c] <1	3	3
GI tract		<1	<1	<1	3
Average Richland resident:					
Bone		[b] 15	<1	15	<1
Whole body	<1	[b] 1	[c] <1	2	<1
GI tract		<1	<1	<1	<1

[a] Not including natural radioactivity.

[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods. Only a few percent of the total dose commitment from strontium-90 intake is received during the first year for each of these organs.

[c] For the whole body dose commitment from ingestion of cesium-137 by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used.

to the surrounding population, with methods detailed in references *1* and *10*. The trend of these estimates with the step-wise shutdown of the single-pass production reactors is indicated by table 12 and figures 14 and 15. For comparison, estimates of radiation dose to the local population from nuclear weapons testing fallout are shown in table 13.

Summary

The 1971 Hanford Environmental Surveillance Program showed continued compliance of the Hanford contractors and their operations with applicable environmental standards. The shutdown of the last of the single-pass cooled production reactors (KE) in January 1971 eliminated the major remaining source of radioactivity released offsite and of population exposure from Hanford operations. No unusual releases occurred causing AEC standards, as given in AEC Manual Chapter 0524, Appendix, Table II, to be exceeded. All measurements of radioactivity outside the plant boundaries were less than 15 percent of the applicable AEC standards. Radiation dose estimates for population groups in the plant environs for 1971 were all less than 1 percent of applicable standards for plant operations. Offsite measurements of other air and water quality parameters also were well within applicable criteria and showed no significant evidence of plant operations.

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Previous coverage in *Radiation Data and Reports:*

Period	Issue
1970	April 1974

Reported Nuclear Detonations, May 1974

(Includes seismic signals presumably from foreign nuclear detonations)

Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States on May 15, 1974. The signals originated at 11:03 p.m., EDT, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

The government of India announced that they had conducted an underground test on May 17, 1974 in the Rajaschar desert. This test was in the yield range of less than 20 kilotons.

Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States. The signals originated at 11:27 p.m., EDT, May 30, 1974, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20 to 200 kilotons.

There were no reported nuclear detonations for the United States for May 1974.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

CALCULATIONS OF DOSE, POPULATION DOSE AND HEALTH EFFECTS DUE TO BOILING WATER NUCLEAR POWER REACTOR RADIONUCLIDE EMISSIONS IN THE UNITED STATES DURING 1971. *J. A. Martin, Jr.* and *C. B. Nelson. Radiation Data and Reports, Vol. 15*, June 1974, pp. 309–319.

Atmospheric emissions of radionuclides during 1971 reported by operators of 10 boiling water nuclear power reactors in the United States were analyzed to calculate resulting doses in the general offsite environment. A recently developed computer program (AIREM) was used to perform the calculations. A sector-averaged diffusion equation, using facility generated onsite annual average meteorology, was used to propagate the emissions from the release point out to 80 kilometers. In 1971, 3.2 million curies of radioactivity were released to the atmosphere from 10 reactors. The resulting whole body population dose was calculated to be 900 person-rem. The health effects associated with this population dose were calculated to be small fractions of those induced by natural background radiation.

KEYWORDS: Atmosphere, boiling water nuclear power reactors, population dose, radionuclide emissions.